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An Ecological Approach to Rehabilitation for Traumatic Brain Injury

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AN ECOLOGICAL APPROACH TO REHABILITATION FOR TRAUMATIC BRAIN INJURY

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ABSTRACT

Advancements in technology, research, and practice are scientifically establishing the relationship between the mind, body, and built environment. In modern TBI rehabilitation medicine, a team of specialists works together to assess the physical, mental, and emotional effects of brain injuries on individual patients and to develop and carry out a plan of action that helps them to overcome, compensate for, and cope with changes in their levels of ability. TBI rehabilitation can integrate holistic practices that better consider an integrated mind-body relationship as well as the built environment as potentially significant factors in supporting functional ability.

This thesis investigates the potential role of architecture, and specifically the design of a setting for traumatic brain injury rehabilitation, based on an ecological framework. Ecology is the study of organism-environment systems. In 2001, the World Health Organization adopted a model of ability/ disability that broadens the understanding of contributing factors to include the social and physical environment. Ecological

psychology serves as a promising roadmap for the new era of neuroscience where a more holistic approach includes the mind-body and environment.

Initial research began with a literature review of the principles, basis, history, and current state of neuroscience, brain injury, and ecological approaches to psychology, design, and science as applied to traumatic brain injury and the design of settings for TBI rehabilitation. Ecological approaches to design call for the design of the built environment to be in synergy with the natural processes of the planet rather than continuing the damaging patterns of industrial history. Ecological validity in science calls for real-world functioning results from research.

Building on principles within ecological psychology, ecological design, and ecological validity, six architectural design guidelines were developed to address these obstacles that focus not just on the patient, but on the entire ecosystem that surrounds the TBI patient community in rehabilitation. These design guidelines include community interaction, encouragement of movement, therapy throughout, authenticity, respite, and multisensory stimulation.

The design guidelines were applied to the design of a prototypical regional comprehensive inpatient rehabilitation hospital for traumatic brain injury, one of the most common emerging prototypical building types for TBI rehabilitation where patients live for weeks or months during recovery. The site selected was in a mid-size regional city on an existing medical campus in a mixed-use walkable community. The primary program elements include an inpatient wing, administrative, outpatient, clinical, therapy, and public areas. A site in Knoxville TN was then analyzed for constraints and opportunities with respect to the overlay of a building program for a Traumatic Brain Injury Rehabilitation Hospital based on the design guidelines.

The thesis project proposes a rehabilitation facility designed according to ecological principles in science, psychology, and architecture with the intent to address the needs and rehabilitation of TBI patients more holistically. The proposal includes a series of distinct features from site design, building organization, spatial affordances, and building systems selected for their ecological impact. The constraint of a steeply sloped site presented a design opportunity to provide an atrium connector that facilitates community engagement with patients who possess a variety of physical and cognitive abilities through multisensory stimulation, multiple modes of vertically traversing the sloped site and multistory building, a rich regional material palette, a west-facing translucent solar screen for variable multisensory effects, and openness, connectivity, and order for intuitive wayfinding. The inpatient wings were designed for more diverse sensory experience with a variety of space scales, multi-function family areas, and outdoor porches. The sustainable design approach includes investigation of emerging laminated timber construction usage for institutional settings as well as environmental control systems that are earth-coupled, save energy, and provide a greater degree of personal control. The ecologically derived design guidelines permeated all scales of design from site selection to details and informed all program areas including multisensory and diverse therapy locations and patient spaces.

DEDICATION

To James

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1 INTRODUCTION

“There is no such thing as a disembodied mind. The mind is implanted in the brain, and the brain is implanted in the body,” says neuroscientist Antonio Damasio. [1] The increasing sophistication of medical technology and advancements in scientific discovery are beginning to uncover the mysteries of the physical operation of the brain. In contrast to the Hippocratic mind-body understanding of health recorded in ancient history, modern Western medicine since the Renaissance approaches mental and physical health along the lines of Cartesian mind-body dualism, disassociating diseases of the body and mind. [2] In the emerging field of traumatic brain injury (TBI) rehabilitation, advancements in technology, research, and practice are scientifically establishing the relationship between the physical structure of the brain and the physical, cognitive, and emotional functions.[3 4 5] What has yet to be addressed is the relationship between the embodied mind and the built environment.

In modern TBI rehabilitation medicine, a team of specialists works together to assess the physical, mental, and emotional effects of brain injuries on individual patients and to develop and carry out a plan of action that helps them to overcome, compensate for, and cope with changes in their levels of ability.[6 7] However, these approaches, even when coordinated between specialists, often leave patients unable to attain functional goals after rehabilitation, with many suffering from lifelong disability, stress, and social isolation.[8 9 10] Emerging models in TBI rehabilitation are integrating holistic practices that better consider an integrated mind-body relationship that is reflected not just in the medical techniques, but also in the design of the physical environment.[11]

Just as holistic approaches address integration of the mind-body system, the emergence of ecological approaches to psychology, design, and science in the mid-20th century offer an even more comprehensive approach to TBI rehabilitation. Ecological psychology is unique because it is based on embedded, embodied cognition, aligning with Damasio's assertion that the mind and body are one, in contrast to traditional Cartesian psychology asserting mind-body dualism.[12] Over the course of its development in the last 60+ years, several major principles have developed from this foundation. The first central principle is organism-environment mutuality: the organism-environment system is the minimal unit of analysis rather than the organism-centric approach used predominantly in medicine today.[13] In other words, focusing on a singular organism/person alone does not provide a complete understanding for their capabilities, but rather both the person and their environment must be considered as an irreducible system. The World Health Organization in its most recently updated framework supports this principle through the inclusion of social and environmental context in its definition of disability.[14] Other principles derived within the framework of ecological psychology have the potential to bridge the gap between physical science and psychology including ecological optics, invariants, direct perception, affordances, the education of attention, and perception-action relationships, some of which are explained in later sections.[15] Ecological design emphasizes the interrelatedness of overlapping organism-environment systems and how the health of one affects the other.[16] Ecological validity in science is defined as the degree of accuracy of research findings in clinical environments.[17] Using ecologically-based approaches, the design of rehabilitation hospitals can not only facilitate holistic rehabilitation of the patient, but also improve the physical and social context in which the patient, their family, friends, care givers, advocates, and the community function together to overcome disability, stress, and loneliness.

Six design guidelines for the built environment of TBI rehabilitation are proposed to address the issues of disability, stress, and loneliness using ecologically based approaches:

1. **Community Interaction** invites direct interaction between the community, families, visitors, staff, and patients to reduce isolation and build empathy.
2. **Encourage Movement** builds brain health as research shows the relationship between physical activity and brain health.
3. **Therapy Throughout** the facility builds ecologically valid scenarios for testing clinical rehabilitation approaches and practicing real-world activities.
4. **Authenticity** in the architecture means elevating the expression of “invariants” (as specifically defined for ecological psychology) such as natural laws of time,

place, composition over “rules”, which are stylistic, simulated, and transitory. Authenticity helps patients with cognitive impairments to perceive and react to their environments more intuitively.

5. **Respite** spaces provide a means of stress reduction through the patient’s ability to escape from overstimulating environments.
6. **Multisensory Stimulation** is carefully considered both to moderate the intensity of and to increase the variety of environmental stimuli to account for sensitivities and varying abilities (including diminishment) in perception.

Together, these guidelines address not just holistic patient issues (mind-body), but also describe characteristics of environmental affordances which promote actions by a variety of people in the greater TBI community that work together to create more synergistic contextual systems in support of patient, community, and world health.

In order to study the potential applicability of these guidelines, a prototypical rehabilitation hospital program is proposed as adapted from a stereotypical regional TBI rehabilitation hospital program provided by a nationally recognized expert in modern

TBI rehabilitation facility architecture. The program includes typical TBI rehabilitation departments such as inpatient rooms, spaces for a variety of types of therapy, and a therapy gym. Spaces such as a café and atrium with public access were added to the program to better facilitate the design guidelines for community interaction. Smaller scale family spaces and outdoor therapy gardens were also added to provide respite and multisensory experiences. Overall, the program adheres to current basic practices with minor but significant modifications to add value from ecological approaches without adding unreasonable cost or complexity. These modifications included the addition of interactive public space at the interior and exterior of the facility, engagement with the public realm, dispersion of therapy functions across multiple spaces and departments, and sustainable design to address the thesis of using ecological approaches in the development of design guidelines to more holistically meet the needs of TBI patients and the community.

Project site selection involves consideration of variables such as prototype generalizability and functional practicality in addition to strategic considerations related to ecological principles. The project site selected is in the mid-size regional city of Knoxville, TN adjacent to an existing acute care hospital campus to align with typical likely locations for these emerging architectural typologies. In particular, site selection was heavily influenced by the design objectives related to community interaction and encouraging movement. The site is proposed not in a remote natural area with respite as the primary driver, but rather in a diverse mixed-use pedestrian friendly urban neighborhood that would provide opportunities for community interface and encourage patients, family, and staff to engage with the surrounding community off-premises as well. While respite is important, this design strategy was reassigned to smaller scale spaces within the building program rather than as a location driver. Understanding the potential alignment of the site selection with the appropriate design principles is a key differentiator of this design approach.

The design proposal applies design objectives at a variety of scales to maximize their utilization in multiple systems. For example, community interaction informed not just the site selection, but also the design of building scale porches and terraces which encourage building users to occupy spaces for rest that also provide gradations of engagement with the community. A significant design solution emerged from an affordance offered by the existing site slope that is an obstacle to the community for users with a variety of abilities, not just TBI patients. By creating an atrium space with movement assistance which enabled patients, families, and community members to more easily navigate the steep slope, the architecture responds authentically to context, encourages movement, creates opportunities for therapy in an ecologically valid sense, and provides a space for community interaction. Multiple levels, scales, and qualities of space facilitated by the grade change and interface with adjacent spaces allows for small areas of respite. Active screening devices, a rich material palette, and operable facades also allow for the potential of a variety of conditions for lighting, air flow, heat, and acoustics. In addition to the atrium space, design objectives were applied to the therapy gym and terrace and patient floor design elements at multiple scales. Overall, the ecological approach in the development of design objectives to address ability, stress and loneliness does introduce new opportunities for the built environment to positively impact aspects of human health, especially as it relates to the embodied brain.

2 TRAUMATIC BRAIN INJURY

2.1 TBI Epidemiology

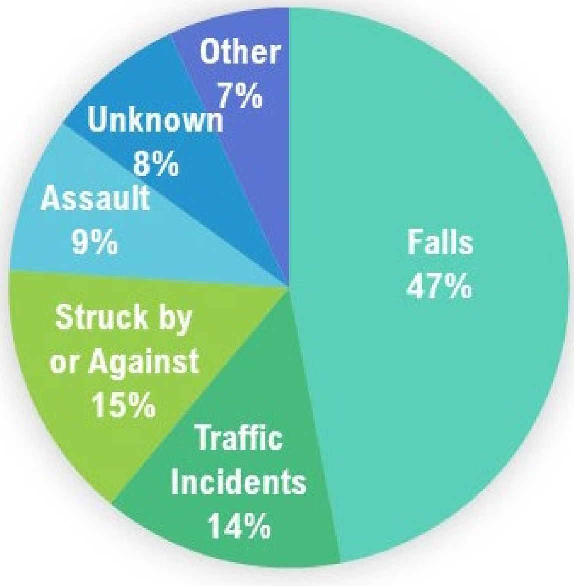


Figure 1: Leading Causes of Traumatic Brain Injury in the U.S., 2013

Traumatic Brain Injury (TBI) is an increasingly significant public health concern. Average Americans might be aware of TBI because they know one of the more than 200,000 war veterans diagnosed with TBI between 2000 and 2011.[18] They might have seen public health campaign media cautioning against the dangers of repeated mild traumatic brain injuries, called concussions, suffered by professional and school athletes.[19] In 2014, TBI caused 2.87 million visits to the emergency department (ED), hospitalizations, and deaths; a number that increased over the previous 8 years by 54%.[20]

In 2014, there were 288,000 TBI-related hospitalizations in the general U.S. population.[21] Falls are the leading cause of TBI-related ED visits, accounting for almost half (48%).[22] Causes of TBI-related hospitalizations vary by age group. For children 0-17 years of age and adults 55 and older, falls were the leading cause of hospitalization.[23]

TBI-related hospitalizations for adolescents and adults aged 15-44 were primarily caused by motor vehicle crashes.[24]

TBI related deaths decreased between 2006 and 2014, but in 2014 still averaged 155 per day.[25] Not only is preventing death still an issue, but also a new public health concern has emerged for chronic conditions that persist or emerge after the initial trauma. Though no official tracking of the data exists, CDC used limited state level studies to estimate between 3 and 5 million people in the U.S. live with TBI-related disabilities[26] A 2010 study found that two years after TBI rehabilitation, 60% of patients were unemployed, and of those employed, 35% were part-time.[27] Children and adults who suffer moderate to severe TBI are more than twice as likely to die within a 3.5 year period following injury than the general population.[28] These statistics indicate that holistic rehabilitation, while more thorough than traditional physical medical treatment, often falls short in helping patients to achieve a high quality of life after injury. Design of the built environment offers untapped opportunities for improved outcomes for both patients and society through consideration of the broader context into which the patient reintegrates. The appropriate design of settings for rehabilitation has the ability not only to mitigate physical obstacles common in the physical environment, but also to afford activities which support TBI survivors intellectually, emotionally, and socially.

2.2 TBI Definition and Classification

The CDC defines Traumatic Brain Injury (TBI) as a “bump, blow or jolt to the head or a penetrating head injury” that disrupts brain function.[29] For initial diagnosis, TBI can be classified as mild, medium, or severe. This classification is typically determined using several assessment methods for best outcome prediction[30]. The Glasgow Coma Scale is an assessment that scores levels of eye response, motor response, and verbal response from 3 to 15.[31] Evolving imaging techniques including CT, SPECT, and MRI are also used in evaluating TBI.[32] Figure 3 gives an overview of criteria used in classifying TBI severity.

Criteria	Mild	Moderate	Severe
Structural Imaging	Normal	Normal or abnormal	Normal or abnormal
Loss of Consciousness	<30 minutes	30 minutes to 24 hours	>24 hours
Post traumatic amnesia	0-1 day	1-7 days	More than 7 days
Glasgow Coma Scale (Responsiveness)	13-15	9-12	3-8
Abbreviated Injury Scale score: Head	1-2	3	4-6

Figure 2: Criteria to Classify TBI Severity

Brain injuries can also be classified in other ways. Penetrating TBI (also called open TBI) occurs when an object penetrates the skull and enters the brain, usually resulting in localized damage. Non-penetrating TBI (also called blunt head injury, or closed TBI) injuries are caused by a force that moves the brain within the skull, such as a sports head injury or automobile accident. TBI may be primary if the injury is immediate, or they may be secondary if damage occurs over time, usually through a reactive process such as swelling or internal bleeding. [33]

In addition to the signs used to define and classify TBI, other symptoms may include nausea, dizziness, fatigue, sensory and perception changes, seizures, headaches, sensitivity, slurred speech, dilated pupils, confusion, psychological and behavioral changes. [34] After subsidence of the initial symptoms, short-term or long-term effects may emerge, persist, or change as the body responds to trauma and begins to heal.

2.3 TBI Effects

Brain Injuries may affect one area or multiple areas, depending upon the nature of the injury. As illustrated in figure 3, scientists are starting to better understand the diverse potential effects of injuries in different parts of the brain. Many of the signs historically ascribed to both mental and physical illness can now be mapped to areas of the brain through imaging techniques correlated to observable patient effects. Figure 4 indicates how damage to specific areas of the brain affects different functions including not only cognitive processes, but also behavior, emotions, perception, memory, physical movement, communication, and basic regulation of involuntary bodily functions such as respiration or sleeping.

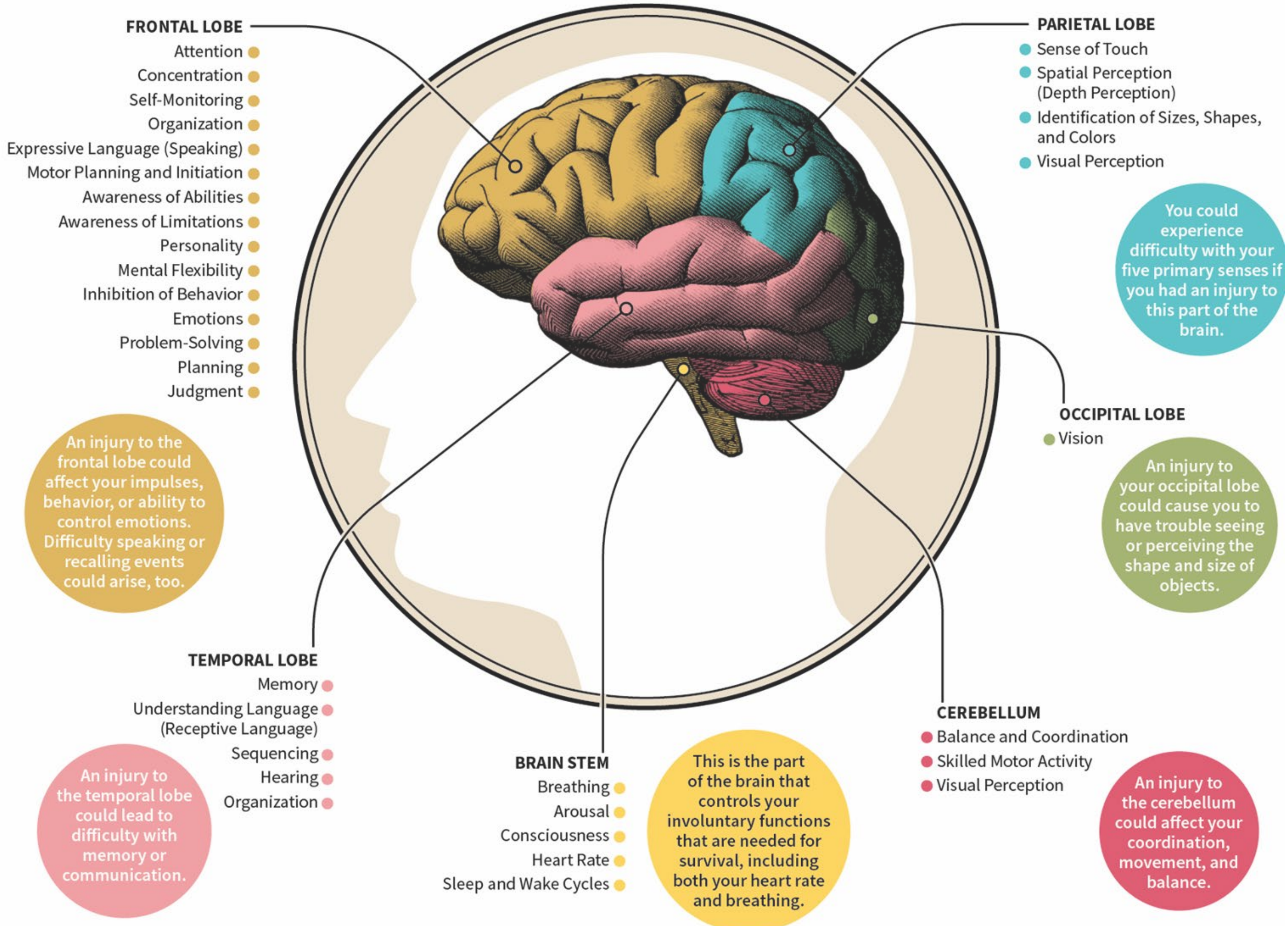


Figure 3: What Happens When You Get a Brain Injury in Different Areas?

Complications which may develop and persist over a longer period of time can include altered states of consciousness such as coma, vegetative state, minimally conscious state or brain death.[35] Even after immediate health threats are addressed, the following effects may last for short or long-term durations:

- **Physical complications** may include seizures, headaches, vertigo, partial paralysis, **sensory problems** (blind spots, double vision, loss of hearing, ears ringing, alteration or loss of smell or taste), and **motor problems**[36]
- **Intellectual problems** may develop under the category of cognitive issues (memory, learning, reasoning, judgment, attention, concentration) or executive function (problem-solving, multitasking, organization, planning, decision making, and beginning/completing tasks).[37]
- **Communication issues** may have both cognitive and social aspects, including difficulty understanding written or verbal communication, difficulty speaking or writing, inability to organize thoughts and ideas, and trouble following and participating in conversations, difficulty understanding nonverbal signals,

problems expressing emotion or subtle differences in meaning, and sometimes inability to use the muscles to form words.[38]

- **Behavioral changes** might include lack of self-control, risky behavior, socially inappropriate behavior, and verbal or physical outbursts. Many patients experience **emotional changes** including depression, anxiety, mood swings, irritability, anger, or lack of empathy.[39]

The ability of TBI patients to interact with the physical environment are impacted by each patient's unique physical, emotional, and intellectual diversity as well as sociocultural factors which are influenced by the built environment. Some specific examples of a direct correlation between brain injury effects and the built environment include:

- sensitivity to bright, strobing, or high contrast lighting and/or sound and an ability to remove the stressor or escape it;[40]
- difficulty with wayfinding including recalling or determining location, orientation, and destination due to limitations in movement, memory, and

perception. Some patients lose the ability to read signage or to clearly communicate their needs to ask for help of others. Patients might experience fear in unfamiliar environments with limited visibility related to past patient trauma [41,42];

- physical constraints in daily activities such as dressing, bathing, toileting, sitting/standing, and ambulation (especially managing level changes) due to impaired balance, proprioception, early or constant fatigue, ability to move limbs, and adjustment to new prosthetics or assistive devices. They often require additional supportive elements such as handrails and/or lifts [43];
- mental health issues in some cases requiring a higher degree of life safety design to prevent self-harm, though patients with more extreme effects are usually housed in a specialized facility or area to better meet their needs rather than a typical rehabilitation hospital; and
- feeling socially exposed or over-stimulated, particularly in light of new appearance or behaviors associated with TBI [44].

Although some brain injuries may have visible evidence such as bruises or wounds from trauma, many of the signs and symptom are not visible and may emerge or persist beyond the healing of visible physical wounds, which is why TBI is often called an "invisible injury". As a result, patients without recognizable signs of injury demonstrating non-normative behaviors or disabilities may be stigmatized or invalidated in social contexts rather than treated with patience and compassion. For example, when they encounter level changes as steps in the built environment that would be understood as obstacles for wheelchair users (visible injuries), TBI patients with TBI (invisible injuries) may be called lazy or uncooperative rather than disabled if they are unable to successfully navigate the steps. These types of encounters lead TBI patients to feel isolated and make recovery more difficult.

2.4 TBI Outcomes

Patient outcomes are affected by a variety of factors. Federal measurement of TBI outcomes awaits further development of standards and collection of data. Some evidence does exist regarding three factors: individual characteristics, social environment factors, and access to care after hospitalization.[45] Research indicates more negative outcomes based on age for those who experience TBI before age 7 or in the oldest age categories.[46] Evidence shows that socioeconomic status, family function, and social support affect outcomes from rehabilitation. [47] Family, spouse or partner, and caregiver support also positively impact a TBI patient's ability to return to normalcy and independence regardless of TBI severity.[48]

In order to address these factors, the built environment of rehabilitation facilities could provide more varied types and scales of spaces that allow patients with unique preferences, conditions, and sensitivities to find spaces they find most comfortable for socializing, eating, resting and participating in activities. Also, providing amenities for families of limited means to be on site and provide support of the patient could be accomplished by creating more family-friendly spaces for family to live with the patient, work remotely from the rehabilitation hospital in a quiet space, and be together in a family scaled social environment with amenities they might want in a home such as access to a kitchen, entertainment, and accommodation for pets. The next chapter will provide more information on the current environment of care.

2.5 TBI Experiences

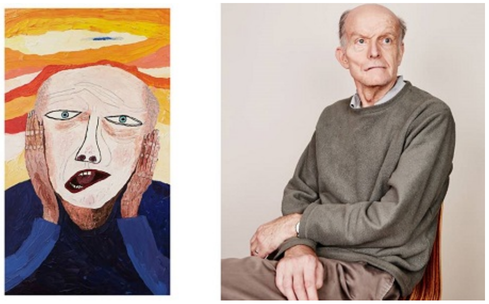


Figure 4: Art of Leon Foggit and Chris Miller, TBI Patient

Four patient profiles from published personal accounts facilitate a phenomenological understanding of the experience of TBI for patients, families, friends, staff, and communities. Each patient represents a different demographic of the broad and varied patient population affected by TBI: male and female, younger and older, single and married, parents and children, and in different geographic regions of the U.S among many other variables. Each of the patients had different TBI causes, circumstances, and effects as well as different rehabilitation experiences. All are optimistic survivors with messages of hope as well as lessons learned about TBI related recovery and ongoing adversity. Figure 4 is artwork by a TBI patient (with photo) to visually represent his experience with TBI.

Figure 5: Kelly Bouldin Darmofal

Kelly Bouldin Darmofal was a high school student when she experienced a severe closed head brain injury from a car accident where her head hit the dashboard. Kelly spent a month in the hospital, starting with an induced coma and slowly regaining her ability to understand, communicate, and move. After her initial stabilization, Kelly had to relearn how to walk, use the bathroom, eat and talk.

Though she had no other physical injuries, the TBI affected many aspects of her mind and body. She experienced diplopia (double vision), bilateral hand impairment (affecting ability to write or type), amnesia (memory impairment), and aphasia (language impairment).

After discharge from the hospital, Kelly's mother chose which inpatient rehabilitation hospital she would enter based on several factors: 1) the facility had a warm and socially supportive environment (colorful, filled with people talking and socializing as opposed to quiet and/or institutional) and 2) the program encouraged (rather than discouraged) family to participate in rehabilitation and/or stay with the patient in the facility. The geographic location of the facility posed an issue being a few hours' drive from their home since it made it harder for friends and family to visit. Although they selected a "social" feeling facility, locked wards for patient safety created a feeling of isolation and loneliness for both Kelly and her mother. Kelly received encouragement by other patients in rehabilitation spaces in addition to her family and staff. She and her mother also gained a feeling of gratitude because they saw other patients who were much more severely debilitated by their injuries. Kelly's mother shared an eye-opening characterization of rehabilitation as a period of physical and emotional adversity, referring to it as the land of in between:

> "The Land of In Between is the ultimate fear… [so] dying can be the mercy of God. In rehab, Kelly and I learned not to be afraid of dying, for living through trauma is scary enough. Leaving this land is the goal, the only goal. You do not leave it by being discharged and going home. You leave by sweat and tears and faith, by physical torture (therapy), by refusal to stay."[49]

Kelly's book shares accounts of interactions with several other patients, each with a unique cause, effect and outlook. Enabling a community of patient support was a positive aspect of the rehabilitation experience, but also there was "no privacy, no quiet, [and] numerous cussing scary people in her group therapy sessions…."[50] Kelly's mother believed it would have helped if Kelly would have been grouped with people her own age and recounted that she believes the facility does this now.

Though Kelly's mother lived with her in her room and went with her to rehabilitation sessions, she occasionally stepped out to run personal errands. One evening, she returned to the room to find a male orderly staring at her sleeping daughter. Fearing for her daughter's vulnerability, although no abuse was indicated, they "fled" the facility after only three weeks, against the recommendations of their doctor. Although Kelly could walk some, she had not yet developed a sufficient level of socially acceptable behavior, a home-care condition for which Kelly's parents admitted they were not adequately prepared. While being at home made it easier for friends to visit, having "no social tact" and "the mind of a kindergartner" after six weeks, they stopped visiting and Kelly fell into a depression. Once home, Kelly was home schooled for several months and went to a different rehabilitation facility closer to home for outpatient physical therapy sessions. Even when she returned to school a year later, she went to outpatient physical therapy every afternoon, where she was consistently told "keep working until you drop" and that she would experience the greatest improvements in the two years following the accident. [51] (A statistic is now disputed by researchers.) Kelly's overall rehabilitation experience can be characterized as a period of very hard work and slow incremental improvement over time.

As Kelly tried to return to a normal life after rehabilitation, she experienced ongoing issues with vision, coordination, confusion, and memory that made it difficult (but not impossible) for her to finish high school. It was only after she returned home from rehabilitation that she had surgery which corrected her double vision. An account of Kelly's mom mentions the difficulty she had selecting daily clothing (such pairing a winter sweater with shorts and sandals) and made clear how Kelly's condition affected her ability to make choices and decisions. She never regained sufficient body coordination to allow her to rejoin the cheerleading squad. Ongoing confusion and slow thinking make driving and wayfinding difficult (she will not drive on the interstate). The support of Kelly's family, particularly her mother, as well as availability of school system disability accommodations, had a significant impact on her outcome. Today, Kelly has finished college and works in special education and TBI advocacy, in spite of ongoing cognitive and physical limitations. She is also married and has children.[52]

Figure 6: Trisha Meili

Trisha Meili, age 28, lived alone and worked on Wall Street as an Investment Banker. While jogging in New York's Central Park late one evening after work in 1989, she was violently assaulted. Unconscious due to a head blow, she was at the lowest possible level for a living human on the Glasgow Coma Scale upon her admittance to the emergency department, which means she demonstrated no eye-opening, motor responsiveness, or verbal responsiveness.[53] Trisha has no memory of the day of the event. Called the "Central Park Jogger" to protect her anonymity, the assault was highly publicized in the media for years due to controversy surrounding the investigation and subsequent conviction of suspects later acquitted.

After twelve days in a coma and seven weeks in an intensive care unit (ICU), which she does not recall, Trisha was moved to Gaylord Hospital in Connecticut for seven months of inpatient rehabilitation, including speech therapy, physical therapy, and occupational therapy. Trisha recounts relearning activities of daily living such as reading, speaking, and telling time. While baking cookies with a rehab nurse in the patient kitchen area of the rehab hospital, Trisha discovered she had entirely lost her sense of taste and smell, which she never recovered. While Trisha provides no description of the hospital environment as it existed during her stay in 1989, she does highlight a day after three months in rehab when she was able to complete a quarter mile run in the community (outside the hospital building) alongside a hospital staff member and community volunteers. This was a chance to achieve a sense of pre-trauma normalcy which she found comforting.

Rehabilitation was not a time of complete healing, but rather enabling her to achieve sufficient ability to live alone again. She experiences ongoing concentration issues. Goal oriented, she still runs despite persisting heaviness in her arms and legs. Also, the willingness of her employer to work with her as she regained her abilities was an important factor in her outcome returning to work. Trisha now works for a variety of nonprofit organizations and as a writer and public speaker.[54]

Figure 7: Bob Woodruff

On January 29, 2006, **Bob Woodruff** was embedded with the U.S. army on news assignment in Iraq when he was injured by an improvised explosive device, suffering a severe open head injury along with multiple other physical injuries. At 44 years of age, Bob was married with four children, and had just been appointed national co-anchor of ABC news. His initial injuries were stabilized abroad before he returned to Bethesda Naval Hospital in Maryland, where he spent 36 days in a medically induced coma. His serious physical injuries required nine surgeries, including partial skull replacement. Initial stages of TBI rehabilitation activity began in at Bethesda Naval Hospital (now called Walter Reed National Military Medical Center) in the days immediately following emergence from his coma.[55]

In their shared book *In an Instant*, Bob's wife's story is particularly helpful in revealing the level of stress suffered by a spouse who must balance the care of four children while wondering if her partner would require the care of a child for the rest of his life. Coping with the trauma of this major life change is a source of stress for the whole family. She was discouraged when her research uncovered a statistic that this stress leads to

Figure 8: Bob and Children

divorce in more than half of TBI patient families. Children's visits to the TBI patient in recovery can be stressful because the patient usually has differences in appearance and behavior.[56] Figure 8 shows an image of Bob with his children two days after awakening from his coma and before his skull plate implant.[57]

Because of his media presence, Bob received many flowers, cards and gifts in his hospital room which were helpful but also overwhelming to manage in terms of volume. His wife played family videos on the hospital room TV during her visits and placed large pictures of his family on the wall. These helped with his memories and motivated him to work harder to recover. Understanding which abilities were affected by injuries took time because doctors are unable to predict the specific effects of all types of brain injury on a particular individual. [58]

Once Bob was able to get out of his hospital bed at Bethesda Naval Hospital, he was given a climbing helmet to wear as protection since part of his skull was missing. Because of the potential for PTSD, the staff carefully referred to it as a "hat" since they worried the word "helmet" might elicit traumatic memories from Iraq.[59]

Bob said nighttime was difficult because he was in pain and felt afraid of the dark. Before his skull replacement, he had major issues with vertigo and balance and could barely get up to go to the bathroom without passing out. Since he was in a military hospital, a service member was always stationed in his room to help prevent falls. Emotions were difficult to control and often he would cry for no reason. Visiting with family for one hour was exhausting. His ability to think clearly improved over time, but he described his thought process as “swimming through Jell-O.”[60]

Damage to the left temporal lobe affected Bob’s speech and language centers. He awakened one night and thought he was writing an exciting story but the next morning realized what he wrote was completely illegible. Bob’s speech was halting and without cadence. He often said the wrong word. Reading was difficult; words were slower, and he had to listen hard to follow a conversation. Surprisingly, he could say phrases in several languages he had learned over the years. He often acted out words and made gestures to try to communicate when he could not find the right words. He also had no sense of social propriety and would tell people exactly what he thought, calling one overweight therapist “porky” instead of her name Peggy, not as a joke, but that was how his brain processed her name when he said it. [61]

Bob ‘s body seemed to be healing faster than his brain. He had good days and bad days but tried to stay optimistic. Once he was able to move around, Bob would roam the halls with his physical therapist, eventually beginning to jog around and sometimes pretending to fall as a joke to scare the staff. [62]

Ten days after waking from his coma, Bob transferred from Bethesda Naval Hospital to New York’s Columbia Presbyterian Rehabilitation Center, where he stayed as an inpatient for three weeks. [63] Bob’s doctor’ recommended inpatient rehabilitation, so Bob’s wife toured rehab facilities closer to home in New York. She observed that they all have a central space she called Main Street that simulated normalcy with simulated stores with plastic fruit and a practice car. Seeing this gave her some fear about the level of ability her husband would be able to regain. She saw that they were mostly populated by older people with a few younger ones who appeared to be recovering from sports injuries or car accidents. Bob would be limited to stay on one floor during rehabilitation

Figure 9 New York Presbyterian Hospital Rehabilitation Patient Room

because of his skull injury effects, so she ultimately chose the place that provided the best views of the river and sky and have space since he would be "trapped like a caged animal," even if it was a "beautiful prison." The image at left shows a current view from one of the patient rooms at the New York Presbyterian University Hospital of Columbia and Cornell (Figure 9).

Moving to inpatient rehabilitation was initially difficult because Bob was starting all over with a new staff in a place where he did not know anyone and there were few people like him, adding to the feeling of isolation. Bob's new psychotherapist told his family, "Say goodbye to the old Bob, meet the new Bob." While in rehab, he had to lean against walls and door frames for balance. He had ongoing pain due to injuries in his head and back. He had occupational, physical, speech, and recreational therapy every day and was exhausted by dinner. Often, Bob had to nap to get through the day. Therapist sessions were grueling. Bob said, "they were not there to go easy on me…the brain takes longer to heal than any other organ", and "one day in rehab felt like a whole week in my former life." [64]

Assessments in inpatient rehabilitation revealed to a greater extent the nature and amount of TBI damage in terms of cognition, memory, and perception. Bob did not want his wife to see his slow rate of improvement, which was discouraging for him despite his generally optimistic outlook. He felt grateful that he had only lost 20 decibels of hearing because of his perspective on hearing loss through a close family member with a hearing impairment. Bob's wife had a few overnight visits where she slept on a skinny cot next to Bob's bed and held his hand, but they both suffered from depression, so being able to be close helped. [65]

Even though his skull repair surgery was weeks away, he was discharged after three weeks to live at home and attend daily outpatient therapy in a facility 40 minutes away by car. Bob's wife had a lot of fear with Bob transitioning to the home environment that they might not be able to manage his medications or keep him from falling, but there were no reported incidents. [66]

Six weeks later, the skull cranioplasty took care of Bob's dizziness and remaining pain. He no longer had to wear a helmet. Improvements in communication were slow. For example, he would say "I cannot read" when he could not sleep. With a good sense of humor, Bob was still able to laugh at himself and his confusion about units of measure, telling his family that he felt "$100,000 better." [67]

Bob shares that even years later "everything is slower" and he is not the same person. Long term, Bob lost 20 decibels of hearing, has a blind spot in his left eye, and still experiences confusion if over exerted. Though he did not return to his original position at ABC News, Bob did return to broadcast journalism in less demanding but still highly visible roles. Bob attributes his healing outcome to the tools of family, exercise, touch, music, hope, faith, and spirituality.[68]

Figure 10: Jill Bolte Taylor

Jill Bolte Taylor suffered a severe hemorrhagic stroke in the left frontal lobe one morning before going to work as a neuroanatomist. Although she experienced some temporary amnesia, she recalls her stroke in vivid detail and recounts the event in both scientific and experiential language. After stabilization, Jill had to relearn basic activities of daily living such as how to walk, read, write, eat, etc.

After a few days in acute care, Jill was discharged home under the full-time care of her mother and climbed up to her second-floor apartment by moving up one step at a time backwards in a sitting position, not in the way she was taught by her physical therapist from the hospital. Contrary to the prevailing patterns of inpatient rehabilitation, she spent most of her initial recovery time sleeping in shifts of 6 hours with 20-minute periods of activity. Progress was slow in learning to walk, toilet, eat with utensils, etc., but the natural instincts and supportive nurturing that her mother used in caring for her as a child yielded results that were to her satisfaction.

During waking periods, her mother engaged her in physical or cognitive exercise, of which she could only do one at a time initially. Rather than asking yes or no questions, her mother asked multiple choice questions to probe the extent of her memory and rebuild connections. For example, for lunch she was offered minestrone, a grilled cheese sandwich, or tuna salad. When she responded that she did not remember tuna salad, her mother served that to help rebuild knowledge.

In her book *My Stroke of Insight: A Brain Scientist's Personal Journey*, Jill provides appendices to help caregivers better understand the abilities and needs of patients with brain injury. In essence the items on these lists help to discover areas of damage and provide emotional, cognitive, and physical support to the patient to rebuild their lives in much the same way a parent helps a child to grow. Jill states that a belief in the patient's ability to recover, the push for ongoing stimulation balanced with patience and rest, and appreciation for small increments of progress are all important factors in promoting recovery. Threats from people about limitations on brain recovery after two years were discouraging and now known to be untrue.

Anecdotes about her home recovery reveal some specific areas of concern with the physical environment. Being at home helped her to reconstruct memories. Watching videos of herself pre-stroke helped her to rebuild ways of speaking and moving. Even though these helped regain ability, Jill emphasizes that she needed people to love her not for the person she had been, but for the new person she would become. Jill compares her desire to learn about the world to a child who learns kinesthetically. Walking down the sidewalk required relearning everything from the differences between walking on grass versus concrete, the importance of not walking over the curb into the street, and that the joints in the concrete walk were OK to step on.

In early stages of recovery, the brain is easily overwhelmed by sensory stimulation which it perceives as noise, according to Jill. She emphasizes the need for sleep rather than the rigorous stimulation and forced schedule used at the time in rehabilitation facilities. In her opinion, it was better to prioritize a few things to work on rather than wasting energy on a broad range of things. She did participate in outpatient speech therapy voluntarily to make a speech that had been arranged prior to her stroke, but she never regained the ability to think and read at the same levels before her stroke.

“I needed people to come close and not be afraid of me. I needed their kindness,” said Jill. Since in-depth conversation was unmanageable, Jill most appreciated when visitors would come for just a few minutes, hold her hand, softly tell her about how they were doing and express that they believed in her ability to recover. Nervous, angry, or anxious people were difficult to endure.

Jill recalls difficulty making choices, understanding how to pick out clothes and get dressed, and socially inappropriate behavior (said whatever she wanted). Jill experienced a major change to her personality and life focus, and she is no longer competitive or intellectually driven. She did not return to neuroanatomy, but instead works as a professor and moved from Boston back to her hometown in Indiana to be closer to parents and siblings. She writes and speaks on enlightenment, neuroplasticity and finding inner peace.[69]

2.6 Issues in TBI Rehabilitation

There are several common themes indicated in TBI literature and in the case-study accounts that affect many stakeholders in the TBI community including patients, family, friends, visitors, staff, and the surrounding community. These can be primarily categorized as disability, stress, and isolation.[70]

Disability. Patients are dependent upon health care staff for a variety of activities as they transition to improved functionality. Each patient has a unique variety of effects from TBI and require physical and cognitive assistance in activities of daily living. For example, they may be relearning how to walk, bathe, dress, etc.

To address issues surrounding disability, rehabilitation environments should facilitate independence. A return to independent living activities requires technology in the form of assistive devices as well as a built environment that provides safety and empowers action for those with impairments in perception, cognition, motivation, and ability. While code compliance, accessibility and principles of universal design are needed to meet the needs of TBI patients in all buildings, rehabilitation hospitals offer a unique opportunity to be responsive to TBI patients who spend all day every day in the building for several weeks.

Stress. Patients may experience stress from injury-associated stigmas, just being in an unfamiliar health care setting, and/or post-traumatic stress disorder. [71 72 73] Families and friends of patients are also coping with major life adjustments and stress. The case study accounts share the physical, intellectual, and emotional adversity of the incremental rehabilitation experience, regardless of the injury / effect. Careful consideration of balancing patient safety and freedom to explore – just walking around is a stimulating and beneficial activity, according to all the patient accounts. Also, accounts share that exposure to diverse sensory stimulation to assess perceptual changes needs to be balanced with an ability to escape or control the source when overstimulated (particularly sound or light). Occupational stress is present among staff in rehabilitation for a variety of reasons such as control, dealing with difficult people and other occupation-related situations. [74]

A second goal for rehabilitation facilities should be the reduction of stress. Stress inhibits healing and makes patients more vulnerable to illness. Patients, staff, and families need access to environments that reduce stress to improve productivity and promote healing.

Isolation. Due to their reduced ability to participate in pre-injury activities in a normative way, research indicates TBI patients often experience isolation and loneliness.[75 76] The difficulty of isolation and the need for social interaction and changes of venue for family members, not just patients, were reinforced by the mother of Kelly and by the wife of Bob in the case study accounts. Depending upon their philosophy of care and age, rehabilitation centers are not necessarily designed with the needs of families and visitors in mind as pointed out in the case study of Kelly when her mother was determining which rehabilitation hospital was best for them.

Therefore, a third goal for rehabilitation environments is to facilitate supportive interaction. A supportive social environment enables the flow of positive energy from staff, family, other patients, and visitors. Families and friends may come for visits or stay overnight, depending upon their relationship and needs. Evidence shows that family support is associated with rehabilitation effectiveness and that social support is a key factor in returning to a high quality of life.[77 78 79]

Rehabilitation hospital facilities should empower TBI patients to achieve their maximum potential for high quality independent living with an ecological approach to facilitate independence, to offer relief from stress, and to enable supportive interaction for staff, visitors, and the community. This thesis looks at how ecological approaches can guide the development of design objectives in the rehabilitation environment which address these issues.

3 TBI ENVIRONMENT OF CARE

The environment of care includes the physical environment, social context, and activities that surround TBI patients during their recovery from traumatic brain injury. The goals of rehabilitation have evolved from basic physical survival to the ability to be employed, to living a high quality of life, to meeting each patient's unique goals in recognition of their different circumstances and abilities. To contextualize the current state of care, one must first understand its history.

3.1 TBI Care History

While ancient writings indicate that brain injury was a recognized condition prior to the 20th century, it was usually fatal. The first dedicated brain injury rehabilitation programs were created after World War I for veterans in Germany and Austria to reduce early retirement. These centers developed detailed evaluations and treatments for neuropsychological issues with the goal of teaching strategies to compensate for impairments and help the injured regain employment. Based on the principles of Gestalt psychology (which emphasizes perception), some of the tests for visual-spatial perception and reasoning are still in use today. Less TBI-specific treatment progress occurred in the U.S. as rehabilitation was operated by state vocational system outpatient services[80]

General health care for U.S. veterans was provided by state run homes following the Civil War, where veterans also received incidental medical and hospital care. General medical and surgical treatment began to be provided for injured veterans in the U.S. with the Treasury Department bill in 1917, but inadequate facilities existed to meet the needs of veterans in World War I.[81] Following World War I, Congress established new benefits for veterans which included vocational rehabilitation, and new hospitals for treatment of neuro-psychiatric conditions.[82] New 1950's VA hospitals had group patient wards which were more open and had almost no privacy except what could be afforded by a curtain around the bed, such as the one from Ann Arbor indicated in Figure 11.[83]

Figure 11: Post WWII VA Hospital Ward

The next significant advances in the field of traumatic brain injury rehabilitation occurred after World War II. Increasing research led to the development of a multidisciplinary team approach which included not only physicians, but also psychologists and speech-language pathologists. Advances in research also supported the development of new strategies in motor planning, visual perception, executive function, and language disorders. Additionally, the fields of physiatry, occupational therapy, physical therapy, psychology, speech-language pathology, and vocational rehabilitation developed rapidly to meet the needs of veterans. The dominant form of care was custodial, either in general hospital facilities or neuro-psychiatric hospitals for those with cognitive or behavioral issues.[84] [85]

The 1970's brought an expansion of TBI rehabilitation outpatient programs for civilians due to an increase in injuries related to high-speed vehicle accidents. One of the first specialty head injury acute care inpatient treatment units in the U.S. was established at Rancho Los Amigos Hospital near Los Angeles, along with special programs for cognitive rehabilitation.[86] [87] A significant contributor in this field, Dr. Ben-Yishay, along with his colleague Leonard Diller at Rusk Rehabilitation at NYU Langone Health, developed programs for brain-related rehabilitation after Israel's Yom Kippur War and continued for over four decades starting in 1978 at the NYU Rusk Holistic Day Program.[88]

In the 1980's, TBI rehabilitation was established as a subspecialty of rehabilitation medicine and the Committee for Accreditation of Rehabilitation Facilities developed dedicated accreditation standards, along with other private sector expansion of practice standards, ethical guidelines and respect for patients' rights.[89] The Facility Guidelines Institute makes a standard typically required by authorities having jurisdiction for facility requirements for rehabilitation departments in hospital and outpatient facilities. While a few hospitals developed specializations in rehabilitation medicine, rehab programs for TBI were primarily contained within general acute care hospital facilities.

In the 1990's, major shifts in U.S. health care delivery changed rehabilitation care emphasis to efficiency, cost control, and reduced rehabilitation time. This necessitated a change to more accelerated and targeted treatment and the development of functional rating scales specifically for TBI patients to better define and justify services to third party payers. It also impacted research because lengths of stay are not long enough to allow historical levels of study to be conducted.[90] Because of the complexity of patient characteristics, injuries, and issues, the translation of narrow evidence-based standards into practice is a major issue. Since multi-modal interventions are required in clinical practice for the highly specialized needs of patients, it has been difficult to develop clear evidence for clinical interventions.

A proliferation of specific narrow rating scales reflecting actual targets of treatment, such as the Community Integration Questionnaire, helped uncover the diversity of TBI effects and led to many measures needing co-calibration. However, researchers recognize that subjective experiences of patients must be considered along with functional measures.[91] The cost and complexity of research to prove effectiveness of different types of therapy for brain injury has limited the ability of the research community to provide decisive randomized control trial studies, but several less-complex studies do provide growing evidence in support of inpatient TBI rehabilitation programs. Strong evidence to inform rehabilitation program and facility design needs development.[92]

3.2 Current TBI System of Care

TBI rehabilitation today has many delivery modes because each patient is different in terms of brain injury severity and type, comorbidities, complications, general health, availability of support, insurance requirements and other factors. Some of the types of TBI rehabilitation programs and settings include:

- Skilled Nursing Facilities, which are separate from hospitals and house patients with require less intensive therapies with an average length of stay for 30-60 days;[93]
- Long-term acute care hospitals (LTACH) for patients with medical complications such as a need for pulmonary or cardiac support with an average length of stay for 25 days[94]

- Home health for patients who are medically stable and seen for therapy at home possibly due to slower rates of recovery or inability to participate in multiple therapies; [95]
- Comprehensive Integrated Inpatient Brain Injury Rehabilitation Hospitals for patients who are sufficiently stabilized, insured, and able to participate in 3 or more hours of therapy per day with an average length of stay of 3-6 weeks.;[96] and
- Other types including Day treatment centers, outpatient rehabilitation, post-acute residential, neurobehavioral, independent living, and vocational rehabilitation as suited to patient needs and abilities.[97]

Figure 12 gives an overview of the modern TBI system of care, beginning with the patient's initial encounter with the health care system after injury and continuing through initial medical stabilization to post-acute care or rehabilitation (which may not be needed for all patients) to the community setting, which includes living independently or with support. The TBI patient journey begins in an emergency department and acute care facility for assessment and medical stabilization, sometimes involving surgical interventions or periods of time in a coma or unresponsive state.

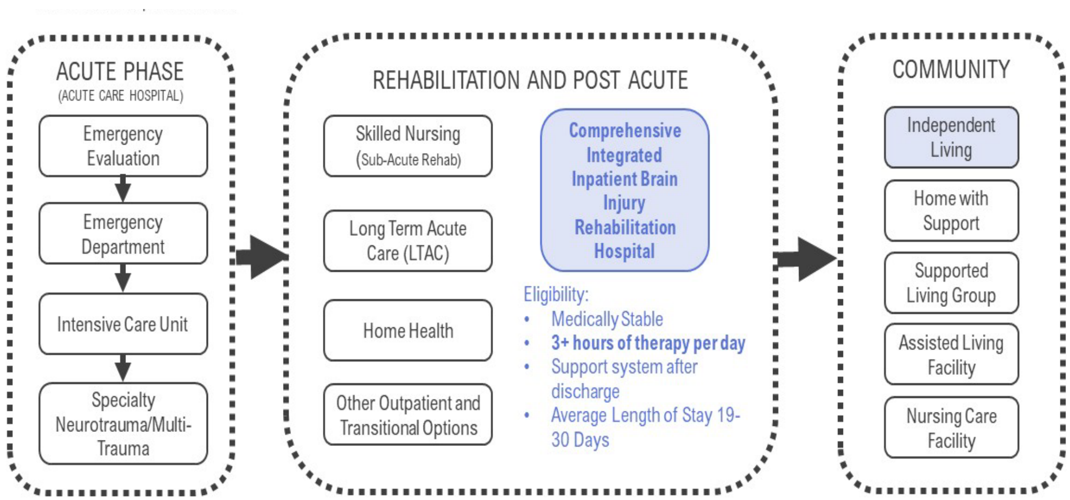


Figure 12 TBI System of Care

Comprehensive Integrated Inpatient Brain Injury Rehabilitation Hospitals are highlighted as they represent a newly emerging facility type. They are separate from acute care hospitals and skilled nursing facilities, which serve patients with a variety of acuity and abilities. Patients are medically stable, spend a majority of the day (and night) in a dedicated facility for the holistic treatment of TBI, and have the ability to attend at least three hours of therapy per day. [98]

3.3 Comprehensive Inpatient TBI Rehabilitation Hospitals

Comprehensive Integrated Inpatient Brain Injury Rehabilitation Hospitals provide medical and rehabilitation inpatient services through a coordinated interdisciplinary care team that assesses and delivers the scope and intensity of care determined in collaboration with the patient.[99] Because the needs of TBI patients are highly variable, the composition of the care team, regimen and duration are uniquely developed for each patient. The types of therapy administered are broadly categorized as cognitive (thoughts and behavior) and physical (sensory and motor).[100]

Patients are typically inpatients and reside and receive care and therapy in the facility 24 hours a day for 3-6 weeks while they undergo physical and cognitive rehabilitation. They may or may not recall arriving in the facility after being transferred from acute care. Patients are in a variety of physical and mental states but medically stable and working towards the goal discharge to a higher level of independent living and quality of life.

Figure 13 graphically summarizes blocks of patient time over a typical "day in the life" of a patient in a comprehensive inpatient rehabilitation hospital. The specific amount of time spent in each type of therapy is customized for each patient depending upon their needs and abilities. Note how much time is given over to other activities. This time period is an opportunity where the facility environment can influence patients in ways that are not part of the structured therapy schedule but still be therapeutic.

Figure 13 Outline of a Day in Comprehensive Inpatient Rehabilitation

3.4 Services and Staff

Figure 14: Occupational Therapy Session

Figure 15: Speech Language Pathologist

Patients recovering from traumatic brain injury interface with a multidisciplinary team to make assessments, set goals, recommend a plan of therapy and coordinate care while monitoring progress. These teams might include one or more the following.[101]

- Physiatrists are medical doctors who specialize in rehabilitation and often lead the rehabilitation team. [102]
- Case Managers / Social Workers coordinate and facilitate treatment services and assist with resources and discharge planning.[103]
- Neurologists are physicians who specialize in diagnosis and treatment of the brain and associated systems. [104]
- Neuropsychologists are specialized psychologists who evaluate patient abilities related to brain function such as the ability to manage decision making and return to work.[105]
- Occupational therapists assist in the development of skills needed for the performance of functional activities for daily living such as eating, grooming

Figure 16: Physical Therapy for TBI

(Figure 14), toileting, home management, fine motor skills and medical equipment training.[106]

- Speech-Language Pathologists assess and treat disorders related to communication, swallowing (Figure 15) and cognitive functions and train patients in the use of assistive technology.[107]
- Physical Therapists focus on evaluation and treatment of movement of the body (Figure 16) using a variety of equipment and environments. They help patients train to perform tasks as well as to use assistive devices.[108]
- Other types of therapists specialize in aquatic, massage, recreation therapy depending upon the applied area.[109]
- Rehabilitation Psychologists focus on helping patients to regain psychological and interpersonal function to the highest level possible. [110]
- Rehabilitation Nurses are responsible for overall monitoring of the patient's bodily systems. They coordinate with the rest of the team to focus on making overall improvement in the patient's level of independence.[111]

3.5 Facilities

Figure 18: Spaulding Rehabilitation Center

Figure 17: Rancho Los Amigos NRC

Technically, comprehensive integrated rehabilitation services can be delivered in a hospital, long term care facility, dedicated rehabilitation hospital or within other health care settings. [112] [113] Many inpatient TBI rehabilitation hospitals are located or are moving to separate campuses or buildings near, but not part of, acute care hospitals, including Spaulding Rehabilitation Hospital in Boston (Figure 17)[114], the Shirley Ryan Ability Lab in Chicago [115], Rancho Los Amigos National Rehabilitation Center near Los Angeles (Figure 18) [116], and Craig Hospital in Denver [117]. Inpatient rehabilitation hospitals like these often serve TBI injury and stroke patients. Proximity to acute care trauma hospitals allows for continuity of care and sharing of support services. Separated rehabilitation facilities can be designed to better meet the unique needs of patients in rehabilitation, which are different from acute care and skilled nursing. Research [118] and review of TBI rehabilitation facilities indicates the typical program elements as indicated below.

Figure 20: Craig Hospital Inpatient room

Figure 19: Craig Hospital Inpatient Bath

Inpatient Rooms. Inpatient rooms are typically separated from other areas of the hospital, either on a dedicated floor or separated zone, and may be locked off for patient safety. While older facilities often have shared rooms (2 patients per room), more modern facilities, like Craig Hospital (Figure 19 and Figure 20) offer individual patient rooms with private handicap accessible bathrooms, storage for patient belongings, and often space for a family member to sleep, such as a convertible chair or fold-out sofa. Overhead lifts are common in these rooms as patients often require mobility assistance, at least initially. Since these rehabilitation patients are typically medically stable, less headwall support infrastructure is required compared to an acute care hospital room. These rooms also must meet FGI standards such as having handwash sinks, windows at eye level, and four feet of clearance minimum around the patient bed. Inpatient rooms are designed with the goal of helping patients to feel comfortable, but it is often difficult to balance with institutional needs for durable cleanable materials and operationally efficient medical equipment such as paper dispensers.

Figure 22: Interior Patient Corridor

Figure 21 Patient Floor Nurse Station

Inpatient Floor Support Spaces. Along with inpatient rooms, support spaces such as nurse stations, supplies, meds, nourishment, laundry, and soiled utility room are also required. In order to maximize patient room access to daylight, corridors and support spaces for staff are often located in core areas with little or no access to natural lighting (Figure 21 and Figure 22). In these conditions, the use of bright colors in finishes is often used to add visual stimulation, but colors often date an older facility. Where possible, alcoves are often used as places to store wheelchairs and gurneys to avoid equipment sitting in the corridor. Other staff work areas are often enclosed for acoustical reasons, but it may mean there is no access to daylight. Because some patients have severe mobility limitations, additional therapy and family spaces also provide needed support on inpatient floors. Often therapy is done in the rooms or corridors of the inpatient wing, so special attention to the design of these spaces for therapy can enhance the quality of staff and patient experience. As indicated previously spaces for families to live, work, and play may also help influence the ability of family to provide valuable additional support during rehabilitation.

Figure 23: Physical therapy space


Figure 24: Newer PT space at Craig Hospital

Physical and Recreational Therapy. Physical therapy and recreation spaces in older inpatient rehabilitation settings are unfortunately often located in hospital interior and/or basement spaces designed for other clinical uses (Figure 23) These spaces often have low ceilings and lack windows and space needed for connection to nature and social support to motivate stressed patients. Physical therapists often use large and heavy specialized equipment to facilitate therapy. Planning for these requires special considerations in terms of structure and clearance. Noise control is needed as the physical therapy space usually accommodates multiple patients and trainers undergoing louder activities. Many hospital systems are proposing to "bring rehab out of the basement" by building newer facilities with daylight, tall ceilings, overhead lift tracks, high-tech equipment, and other features, which greatly improve the patient experience. One example is Craig Hospital (Figure 24), which has an overhead lift track in a tall space with large expanses of windows for light and view.


Figure 26: Aquatic Therapy Pool


Figure 27: Music Therapy Space

Special Therapy Spaces. Therapy spaces with special equipment include large and small simulation spaces, pools, and ADL (Activities of Daily Living) spaces which allow for engagement of a variety of real or simulated activities such as residential living, cooking, driving, etc. Aquatic therapy spaces may be larger or smaller spaces with energetic finishes, daylight and views, climate control for year-round use and specialized equipment such as lifts and platforms that provide comfort and mobility assistance to patients (Figure 26). Simulation spaces help patients practice movements such as getting in and out of real cars or even airplane seats, and even art and music spaces that feel more like a lounge than an institutional space (Figure 27) Simulated residential kitchens and laundry spaces allow patients to practice food preparation and laundry with guidance from therapists. The National Intrepid Center of Excellence in Bethesda, MD is a new facility offering high-tech digital environmental simulations. The CAREN magnetoencephalography (MEG) is for analysis and training of patient movement (Figure 28). [119]

Figure 28: Computer Assisted Rehabilitation Environment (CAREN) at NICoE

Figure 29: Outdoor Respite Space

Respite Spaces. Patients with brain injury often report sensitivity to light and noise.[120] Additionally, emotional control may be difficult. Respite spaces for reduced stimulation provide a sanctuary for staff, family, visitors, and patients during a time of stress (Figure 29). They often have connections to nature for positive distraction and stress reduction. Respite spaces should allow for small groups or individuals.

Figure 30: Art in Public Spaces

General Public Spaces and Waiting. Between therapy sessions, patients rest, socialize, or engage in other informal activities until their next scheduled appointment. Returning to the patient room is not generally encouraged, so facilities offer a variety of space types to accommodate in-between times. These spaces often also serve as lobbies and entry atriums where patients can see visitors without going into patient rooms. At Rancho Los Amigos, art installations such as this ten-foot mandala provide a unique type of stimulation (Figure 30). Smaller seating groups are preferred, even if they are within larger spaces. An effective public space might be a space for walking, observing, or sitting to rest.

Figure 31: Rancho Los Amigos Lobby

Figure 32: NICoE Imaging Space

Clinical Spaces. Clinical offices and meeting spaces accommodate individual and group meetings with a variety of specialists such as psychologists, speech therapists, etc. Clinical assessment spaces with equipment (Figure 32) are for measuring various functions such as hearing, vision, or advanced brain imaging. Because of complex requirements related to infrastructure, acoustics, vibration and light control, these spaces are often interior rooms with no windows. However, windows are preferred in these spaces for daylight and views for the benefit of both staff and patients. While larger facilities offer imaging services, those associated with a larger hospital campus control costs by utilizing central campus imaging departments in other facilities.

Figure 33: Dining in Entry Hall

Figure 34: NICoE Seating Area

Dining. Central dining facilities are often easier for health care providers to maintain than distributed small cafes, so they are a common feature in rehabilitation facilities. There is an opportunity for rehabilitation hospitals to learn from commercial cafes in improving patient and staff satisfaction with varieties of dining settings with distinct attributes of scale, lighting, furnishings, etc. For example, dining at the entrance hall of the Swiss Paraplegic Center in Nottwil, Switzerland feels more like a sidewalk café because it is daylit, open, multilayered and works as a public circulation space (Figure 33). Alternatively, smaller seating areas can create a more intimate experience, which may be preferable to some. The National Intrepid Center of Excellence has smaller seating areas with outdoor views where people can bring their own food from elsewhere (Figure 34). Note that not all seating has to be geared towards wheelchair users. Those with a variety of abilities are best accommodated with a variety of seating options. Other options include interior residential settings or outdoor patio dining.

Figure 35: Hospital Loading Dock

Facility Support. Facility Support Spaces are required such as loading dock, building systems spaces, generators, housekeeping, food service, storage, and waste (Figure 35). These are separate from patient and public areas and should be connected via a network of staff corridors and elevators to provide service to all areas of the hospital. These spaces are typically located in basements and roof penthouses, but in flood-prone areas, newer hospitals are locating these spaces on intermediate floors. Areas overlooked by patient areas require screening from view. Large hospital systems may need truck access, or if part of a medical campus, loading for related facilities may be accessed for smaller trucks and vans the work from a central medical campus hub.

Figure 36: Shirley Ryan Ability Lab Ambulance Entry

Figure 37: Rancho Los Amigo Public Entry

Vehicle Access and Parking: Patients arrive at rehabilitation hospitals by ambulance or transportation by care givers. Main patient entrance areas for public lobbies may be near admissions, or a separate entry can better accommodate ambulance heights and patient gurneys. A separate path to access the patient floor for gurneys should be provided for patient and family arrival. The relationship of a covered drop off to the main entrance is a key adjacency and is necessary for weather protection as many patients require more time and assistance transitioning from vehicles. For example, at Shirley Ryan Ability Lab in Chicago on an urban site, the ambulance entrance is accessed form the parking garage and covered in bold graphics to draw attention to the entrance (Figure 36). The long linear circular drop off at Rancho Los Amigos is off to the side of a smaller canopy indicating a more pedestrian scale. The drop off area is paved like a public plaza for use during special events (Figure 37).

4 ECOLOGICAL APPROACH TO TBI REHABILITATION

In 2001, the World Health Organization (WHO) made a major change in its International Classification of Functioning, Disability and Health (CIF) shifting from previous mechanistic models of disability which focused solely on the person, to a systemic model which adds environmental factors, thus recognizing the role of the environment in the disabling process.[121] An important core element of this shift is in changing from the understanding of disability as solely an organism-focused concern to an activity-focused concern that includes external factors. Figure 38 is a diagrammatic representation of the WHO 1980 Model of Disability. Figure 39 is a diagrammatic representation of the WHO's 2001 updated model of ability. While the 1980 approach is a medical model focusing on the pathology, the 2001 approach shifts to a functional model emphasizing not the disease, but the activity. Curing a pathology is not the same outcome as restoring function. The WHO recognized in the 2000 model that external factors play an integral role in activity.[122]

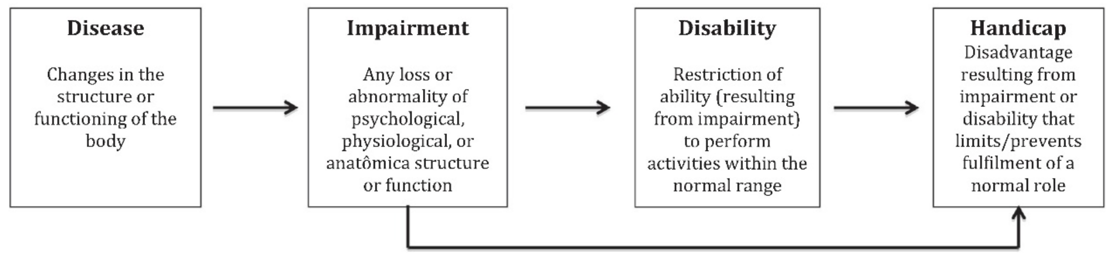


Figure 38: WHO 1980 Model of Disability

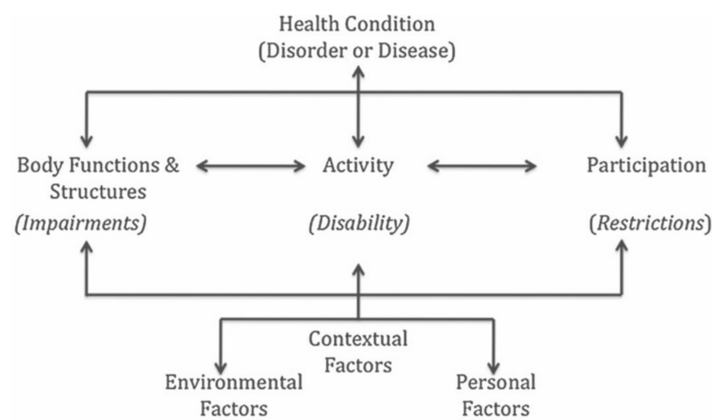


Figure 39: WHO 2001 International Classification of Functioning, Disability and Health (CIF)

Theoretical transitioning from the 1960's era medical model with a linear organism-limited definition of disability to the 2001 systemic model of dynamic and interrelated personal and environmental factors outlined above has important implications for emerging shifts in rehabilitation. For example, the action of walking is not only dependent upon the organism-centric factors such as person having the physiological structures needed to walk, a desire to walk, and the absence of physical health conditions that indirectly restrict movement such as asthma. The updated definition adds consideration of personal factors such as emotional or cognitive conditions, fitness level, age, or past experience, and environmental factors such as the slope, texture, and hardness of a walking surface. Traditional rehabilitation practice based on theories of the motor control approach for relearning mechanisms is slowly beginning to shift to a functional approach based on ecological psychology which recognizes activities and behaviors as *irreducible* systems of organism-environment. [123] This theoretical shift elevates the importance of a more holistic and systematic approach considering personal factors including emotional and cognitive health as well as the design of the built environment for health.

Ecology is the study of organism-environment relationships. [124] Building on the broader approach of the WHO in proposing that contextual factors affect the ability of a person to perform an action, ecological theories in a variety of fields can support investigations of the characteristics of effective systems. Research in the areas of ecological psychology, ecological design, and ecological validation can supplement the thinking behind the design of organism-environment systems that enable specific activities and behaviors.

4.1 Ecological Psychology

Ecological psychology, developed in late 20th century by James Gibson and others, describe several principles inherent to the organism-environment system and provide a new theoretical underpinning to functionally effective design strategies for the built environment. First is the concept of the organism-environment system which is essential to the definition of activity. They are inseparable. [125] Considering an activity as a function of human and environment,

Figure 40 proposes a graphic representation of the impact of animal and environment needed to produce an action.

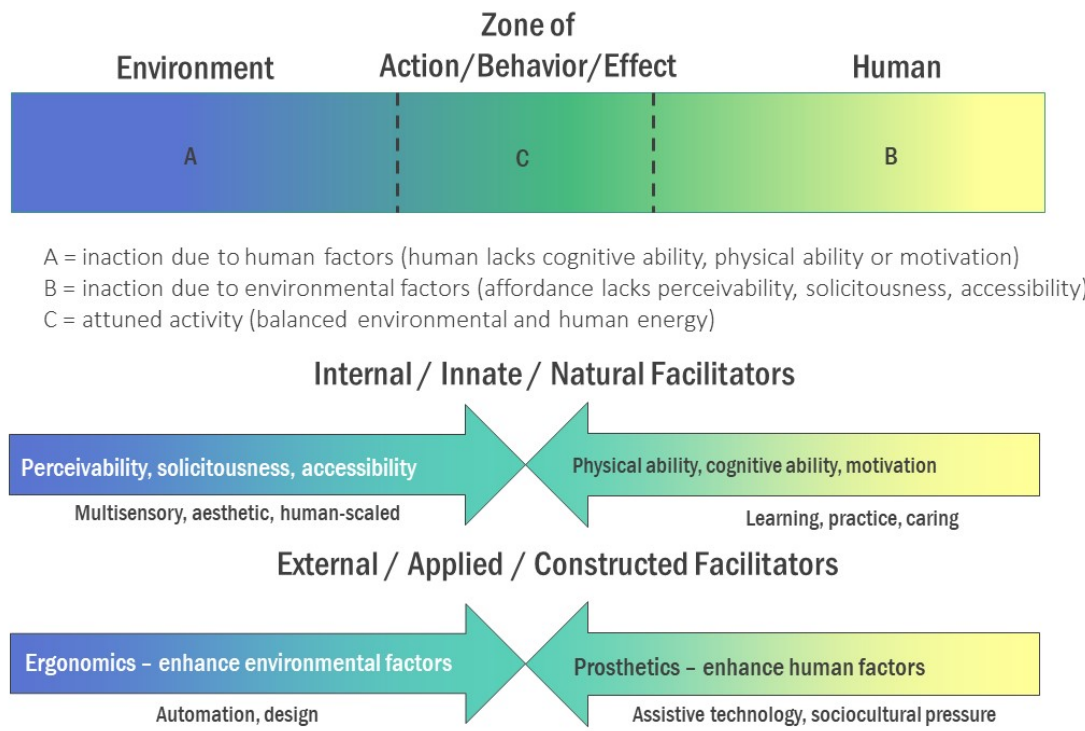


Figure 40: Ecological Psychology Concept of Activities as Organism-Environment Systems

The second concept important to rehabilitation from ecological psychology is the theory of direct perception, which indicates that the perception-action relationship is not causal, nor is it mediated by an internal neural process as proposed in traditional cognitive psychology. Rather, perception-action systems are self-organizing, complementary, and mutually dynamically responsive. [126] [127] [128] In other words, a person's perception of the environment is direct, not an impoverished mental image filled in by memory or computer-like processing. [129] [130] [131] Perception involves exploration and action feedback to acquire information, which comes directly from the environment, which is governed by the laws of physics, not from a mental construct of the environment. [132]

Optic flow refers to the patters of light by which we perceive visual information. Reliable patterns in the structure of optic flow are called invariants, which are based on the laws of physics. It is the apparent motion of objects caused by relative motion of the observer. [133]

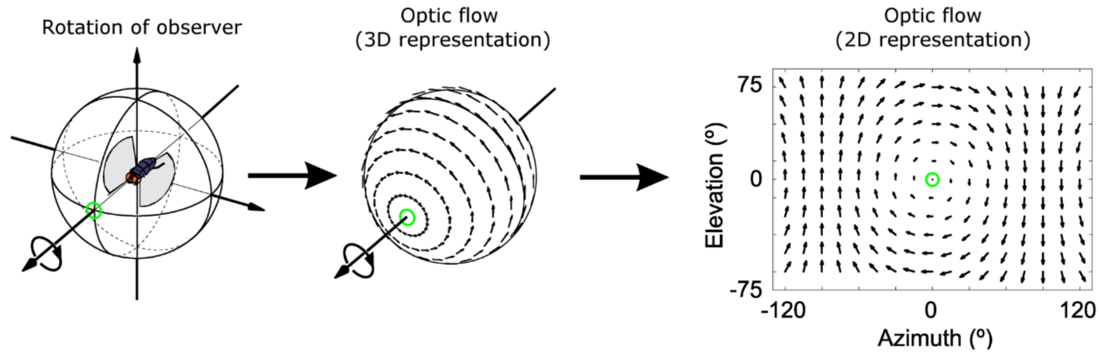


Figure 41: Optic Flow Diagram of Flying

An example of this given in ecological psychology is the outfielder problem which considers how a baseball outfield player moves to the right place at the right time to catch a fly ball. Physicists have discovered the mathematically calculable trajectories to predict the ball's location. Traditional psychology posits that the human mind observes the ball, makes a mental calculation, and moves to catch the ball at the appropriate time. Perception and action are treated as separate and sequential activities. The intake of information about the variables affecting the ball's trajectory and speed happen before movement to catch the ball. The ecological approach to the outfielder problem is that the outfielder may not perceive all of the variables that allow for the mathematical calculation of the ball's trajectory. Rather, the outfielder is simultaneously moving and perceiving until they reach a position which matches a successful pattern of optic flow.[134]

The ecological approach to psychology as it relates to direct perception supports the notion of affordances. Affordances are the term used in ecological psychology to indicate the activities permitted by an object, place, or event. What is afforded depends on the animal and its ability to perceive and act. For example, a low wall may be perceived by a child as a surface on which to use as a table or counter, but an adult may perceive it as a place to sit. Effectivities are the potential behaviors or activities a person or animal may perform in response to an affordance. [135]

> "Whether an animal flies, swims, walks, or slithers; whether it pecks, nibbles, sucks, or licks; whether it smokes, watches television, or mugs old people will determine the affordances it can detect. Because information specifies behaviors that are afforded, and because different animals have different sets of effectivities, affordances belong to the animal-environment systems and nothing less."[136]

Ecological psychology posits, like the WHO, that activity is not just the ability of a person is dependent upon external factors, including the environment. Ecological psychology goes a step further than the WHO in the principle that the most basic increment of definition of any activity must include both the animal and the environment as a system and that the affordances of the built environment are determined by their fit with the person or animal performing an action.

4.2 Ecological Design

Initially published in 1996 by Sim Van der Ryn and Stuart Cowan, the book Ecological Design reinforced an era in architecture and planning that more thoroughly considers ecological systems in the design of the built environment to build a more sustainable world. The framework proposed by this movement involves more detailed consideration of large and small ecosystems that are impacted by flows of energy, water, and materials in the built environment. Five design principles are proposed which align with sustainable design goals: generating solutions from place, ecological accounting to inform design, designing with natural systems, everyone designs, and visible connection to nature. [137]

4.3 Ecological Validity

Ecological validity refers to the generalizability of research results, not just externally with other researchers, but also clinically and in real-world conditions.[138] The concept of ecological validity in science leads to functional outcomes when research is applied in clinical and real-world settings. This is important because clinical assessments for measuring ability of TBI patients are based on research models that do not guarantee functional outcomes. In order to better assure functional outcomes, research can be validated through real-world and clinical trials with better ecological validity.[139]

5 DESIGN GUIDELINES

Ecological principles point to major considerations in the design of the built environment. First, the design of built environment is an integral part of the ability of patients to perceive and act. In an ecological built environment, a novice can act with the ease of an expert because the environment facilitates it. Second, affordances in the built environment invite certain actions through their ability to be perceived and aligned with a person's motivation and capabilities. If a person needs to rest and a low planter wall is nearby, they may sit there to rest not because it was designed for sitting, but because it affords sitting. Understanding the potential of the built environment to direct action through affordances empowers designers to help with the resolution of prioritized issues. In the case of traumatic brain injury, the three primary issues identified are disability, stress, and loneliness. So, the next step is to determine what types of actions are best afforded for which users and to guide the design of the built environment to support them. The following six design guidelines are proposed as a way of providing affordances to overcome the issues of TBI patients.

5.1 Community Interaction

Figure 42: Art Show of Rancho Los Amigos National Rehabilitation Center

Figure 43: Wellness Fair and Race at Rancho Los Amigos

TBI Rehabilitation hospitals should have an accessible inviting space open to the public for the community to interact with brain injured patients, families, and staff in a safe and comfortable environment where a patient experiences a non-stigmatizing social interaction with a member of the community by engaging in informal activities such as a light meal, beverage, and/or an event (such as a patient art exhibit or live music). For example, Rancho Los Amigos National Rehabilitation Center supports public art shows of work developed by patients in rehabilitation (Figure 42) and other events such as a wellness fair on the grounds of the rehabilitation center (Figure 43).

TBI patients and families often suffer from loneliness and isolation because cognitive, physical, and social disabilities of TBI patients prevent them from engaging in their pre-injury activities in a normative way. Individuals in the community are often unsure how to interact with TBI patients because their behavior is often outside of sociocultural norms. [140]

Figure 44 Direct Interaction in Urban Environments

Figure 45 Suburban Commuters in Separate Cars

Building the community's familiarity with TBI patients through direct contact has been demonstrated to improve understanding and benevolence towards disabled patients more than disengaged informational programs. [141] Research indicates that direct engagement with the public realm also improves resident health and well-being and reduces stress. [142] Regular community members in a shared environment start to recognize each other and gain a better understanding of each other. Ulrich's theory of supportive design research indicates that humans react positively and pay attention to caring or smiling human faces.[143] As posited by the Theory of Social Learning, observing public behavior in others also helps TBI patients to learn about sociocultural norms[144].

Affordances for community interaction start at the level of context and extend into the design of the site, building spaces, and details. Initial site selection involves consideration of a site where the community infrastructure and context support direct personal interaction (Figure 44). Mixed use districts support this goal as they enable the unmediated direct contact of pedestrians in the public realm (sidewalks, parks, plazas, etc.). Many suburban and rural contexts do not enable direct interaction because although they may occupy a common space physically, the automobile acts as a buffer to the environment (Figure 45). There are fewer limited, often only intentional, direct human interactions, and there are fewer public spaces experienced directly by the population in day-to-day living. Resorts in remote natural settings are historically associated with a variety of types of medical rehabilitation because of exposure to clean air and sunlight in contrast to historically polluted cities. However, the diversity of interactions in these resorts is limited to others in the same health community and does little to improve the community's sympathy and understanding of the plight of the TBI community because of its isolation. With human health as a valid concern for urban areas, designing for sustainability at every level further enhances the benefits of an urban context by supporting cleaner air, water, materials, and introducing elements of nature. Being associated with a positive narrative of improving the health of the city also helps build a positive image, builds a memorable narrative, and increases the prominence of the project. A sustainable approach to development on an urban site offers great potential for community interaction at multiple levels.

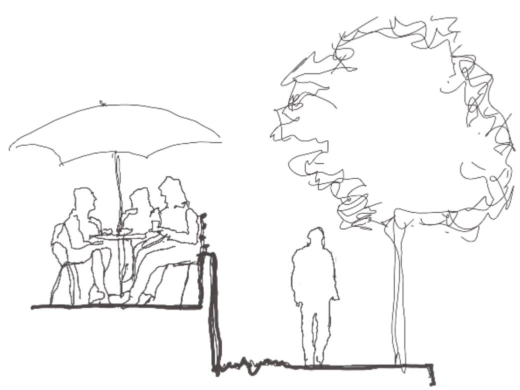


Figure 46: Sidewalk-Porch Relationship in Section

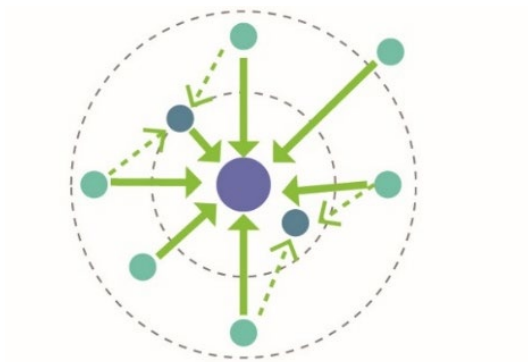
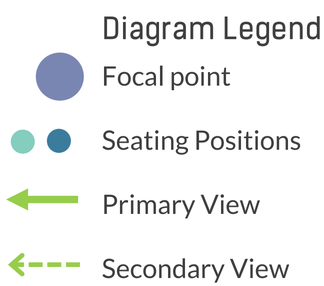


Figure 48: Space Plan around Focal



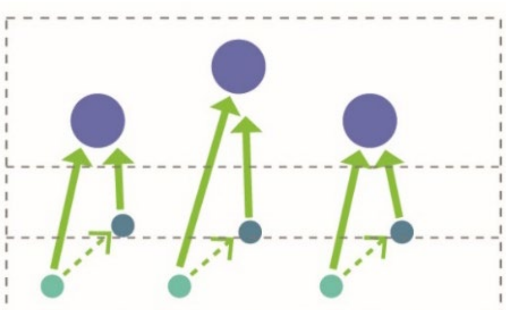


Figure 47: Gradient of Intimacy Spatial Relationships

At the level of the building design, entrances, porches, and terraces should engage the public realm (road, sidewalk, plaza, etc.) where patients, families and staff see and hear people outside the site engaged in normative public activities such as walking, talking, playing, driving, etc.. Often institutional occupancies are designed with limited openings to the outside public realm, ostensibly for security reasons, but leading to reduction in the experience of building users through access to the outside, but also reducing “eyes on the street” as Jane Jacobs, describes the relationships that improve the safety and vibrancy of the urban realm. Aspects of the building which affect the interface with the public realm include elevation differences (Figure 46), window / façade transparency, operable doors and windows, and sufficient space and amenities to allow sitting, standing, or gathering of small groups.

Characteristics of spaces which invite comfortable community interaction include a focal point (Figure 47) and a gradient of intimacy (Figure 48) that provides a positive distraction. The positions of those who interact within the space are distributed at different distances and directions from the focal point(s).

Figure 49: Spaulding Rehab

Figure 50: Therapy Garden Trail

Spaulding Rehabilitation Hospital (Figure 49) in Charlestown, Massachusetts, designed by architects Perkins + Will illustrates several strategies for community interaction. First, the project was developed in an urban area connected to a public greenway on the waterfront. The adjacency of Boston Harbor provides natural viewsheds and activity amenities that attract visitors and relieve stress for the building users, including accessible fishing, a therapy trail, connection to the harbor walk, a dining plaza, and a public plaza.[145] The layout of paths around the building engages with rehabilitation-related outdoor spaces, such as an outdoor therapy garden trail (Figure 50), and the first floor of the building, which has spaces open to the public, including a pool used by the community in the evenings. The site plan (Figure 51) clarifies the relationship between key interior and exterior spaces at grade level.

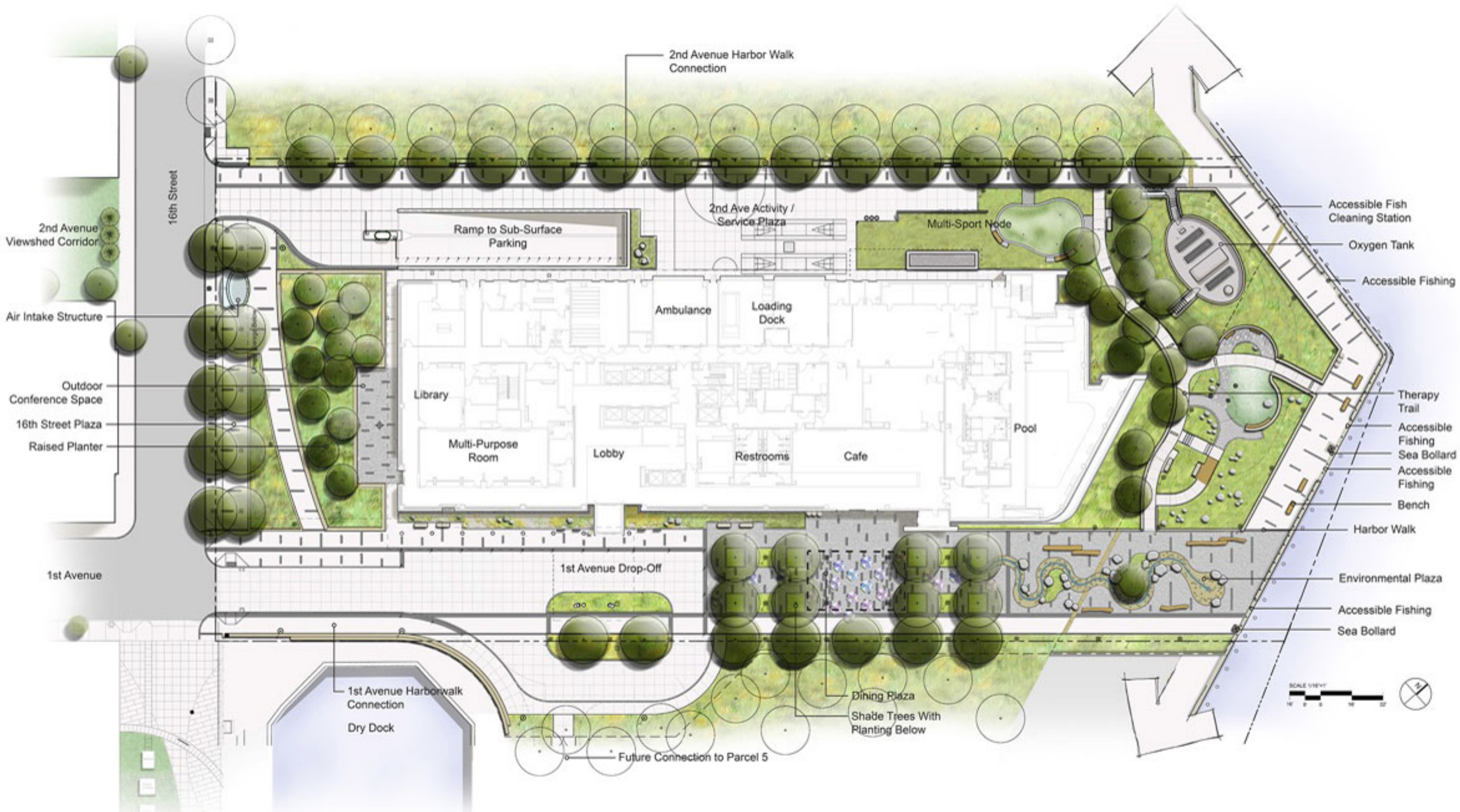


Figure 51: Spaulding Rehab Site Plan

Figure 52: Spaulding Rehab Hospital Dining

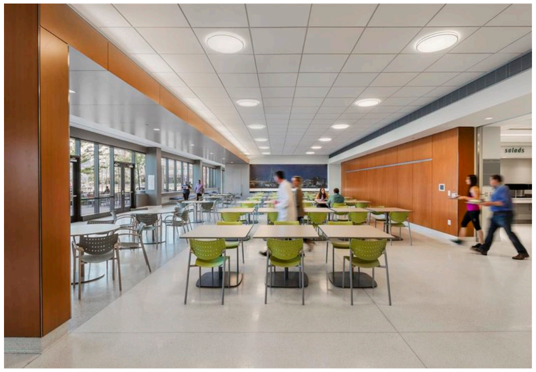


Figure 53: Spaulding Cafe adjacent to Dining Plaza

Second, the project engages the public rights of way with public spaces and activities. The dining plaza (Figure 52) is located adjacent to a pedestrian thoroughfare between the street and the harbor, passing by the main hospital entrance so it has diverse pedestrian activity that allows for passive and active direct encounters. (Figure 53). The scale of interactive spaces inside and outside the building invites gatherings of small groups for resting or dining. Plantings improve the quality of the urban environment and provide partial shade to the outdoor areas. Full height transparent facades with several operable sets of doors encourage visual and physical connections between the hospital and the public realm.

Third, a sustainable and resilient design approach elevated the prominence of the TBI rehabilitation hospital as an exemplar in the communities of rehabilitation, urban redevelopment, and architectural design. The building illustrates strategies of daylighting, natural ventilation, biophilia, and sea level rise responses for resiliency and sustainable design and was certified LEED Gold. [146] [147]

Figure 54: Thomas Menino Park

Revitalization of the formerly blighted sight also sparked the construction of Thomas Menino Park, new handicap accessible playground adjacent to the hospital (Figure 54). By creating a design with a clear narrative, the project raises the awareness of larger issues of disability with the general public and provides an engaging distraction for rehab patients who overlook the park.

Figure 55: Rancho Los Amigos National Rehabilitation Center

Rancho Los Amigos National Rehabilitation Center in Los Angeles, designed by Smith Group JJR, was also designed with outdoors spaces for public events. The plaza in front of the main entry and planted seating and garden areas is inviting to visitors and patients alike (Figure 55). The dominant screen element at the entry façade also reinforces the narrative in the community regarding Rancho's rehabilitation program as a place that integrates and appreciates art. The facility hosts not just art shows, but also festivals and recreation events int the large plaza out front (Figure 42 and Figure 43).

Also of importance is consideration of the relationship between the pedestrian building entry, the public right of way, and the vehicular covered drop off. Craig Hospital in Denver, designed by Smith Group JJR, addresses both conditions by placing the entry at

Figure 56: Craig Hospital Entry

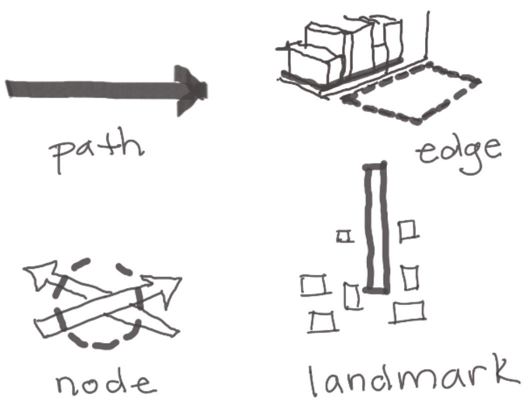


Figure 57: Lynch's Elements of Legibility

a corner in a mixed-use walkable district. The elevated entry patio connects to the district sidewalk, while also being accessible via a ramp accessed from the covered drop off which is located to the side of the building (Figure 56). Overall, strategies for community interaction can be integrated at all scales of design, including the site selection, site planning, building planning, space design, facades, furnishings, and details.

5.2 Encourage Movement

Rehabilitation facilities should encourage patients and building users to increase physical activity through exploration and moving throughout and around the facility. Provide engaging destinations and stimulating paths, entrances, porches, and terraces where patients, families and staff see and hear each other. Make wayfinding easy and intuitive. Research indicates that physical exercise has a positive effect on cognitive performance and brain plasticity (related to healing). [148]

TBI patients can have issues with wayfinding due to lack of memory, reduced concentration, and perceptual impairments such as double vision or loss of hearing [149] [150]. To invite movement as part of the goal of rehabilitation, leaving the room and

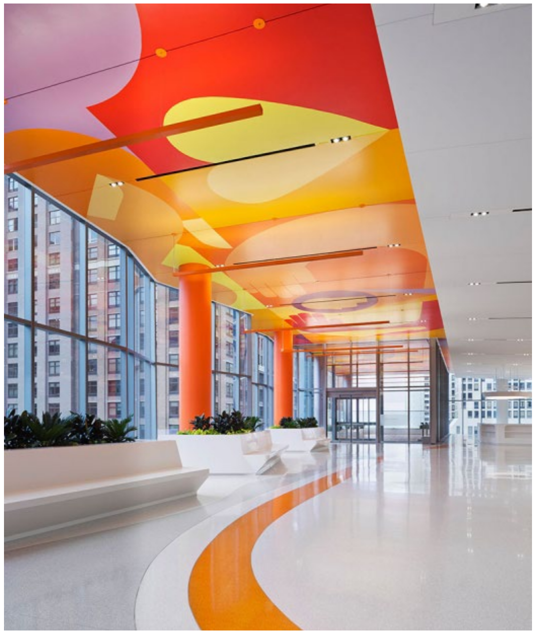


Figure 58: Shirley Ryan Ability Lab Entrance Lobby

moving to different spaces needs to be incentivizing, legible, safe, and comfortable. Ullrich's Theory of Supportive Design proposes specific strategies that provide safety, comfort, and positive distractions.[151]

To alleviate difficulties with wayfinding, Kevin Lynch's research indicates that paths, edges, districts, nodes, and landmarks provide experiential legibility (Figure 57). [152] Experiential wayfinding shows preferences for landmark cues by seniors, often who suffer from cognitive decline.[153] Research also shows that wayfinding is faster and easier in circulation paths which align and meet at orthogonal corners [154] Transparency between spaces allows building users to see into a space before they enter, reducing worry about entering the wrong space.

Strategies for encouraging movement can be applied at multiple scales. Site selection which considers locating the facility in a walkable pedestrian district with desirable destinations allow the rehabilitation experience to extend beyond the property, such as Trisha Meili's (one of the TBI patient experience case studies reviewed earlier) joy with being able to go running with staff and volunteers outside the hospital.

Figure 59: Color Coded Seating Areas

Figure 60: Shapes and Colors for Wayfinding

The Shirley Ryan Ability Lab in Chicago, Illinois, designed by HDR, Gensler and Clive Wilkinson Architects, takes a particular approach with the use of color finishes throughout the facility to encourage movement.[155] At the entry, contrasting floor and ceiling elements delineate colorful sinuous pathways through open spaces to encourage exploration (Figure 58). Different coloration is also used for seating areas at different ends of the corridors to differentiate them as landmarks (Figure 59). Color coding and shapes also help with wayfinding through their association with specific departments. (Figure 60). Each floor has an association with a department related to a type of therapy. Softer colors are used in the "Think & Speak" area, while strong colors are used in the "Strength and Endurance areas". [156]

Figure 62: Basel Rehab

Figure 61: Entry Courtyard

Basel Rehabilitation in Switzerland, designed by Herzog and DeMeuron (Figure 61) takes a different approach to encouraging movement. Rather than emphasizing paths of movement, the plan districts/departments are differentiated through landmark courtyards to facilitate wayfinding throughout the building. According to the architects, this design is experientially analogous to exploring a small town, with courtyards creating streets and plazas in front of smaller residences.[157] The courtyards introduce natural light and views to the core of a multistory deep floor plate. As indicated in the plan (Figure 65), the courtyards are dispersed across the floor area, with some connecting in plan to exterior areas, while others remain completely enclosed by interior space. The largest courtyard indicates the main entrance from the south façade creating a recessed front porch entry (Figure 62). Each courtyard has a unique character which facilitates their usage as wayfinding landmarks. The therapy pool, though enclosed, also acts as a landmark through its unique qualities of contrasting geometry and material at the roof level (Figure 64). One courtyard is filled with water (Figure 66). The French garden on the north side also serves as a landmark for the facility's central open stair (Figure 67).

Figure 63: Therapy Garden

Figure 64 Pool Roof Light Well

Figure 65: Basel Rehab Ground Floor Plan

Figure 66: Water Courtyard

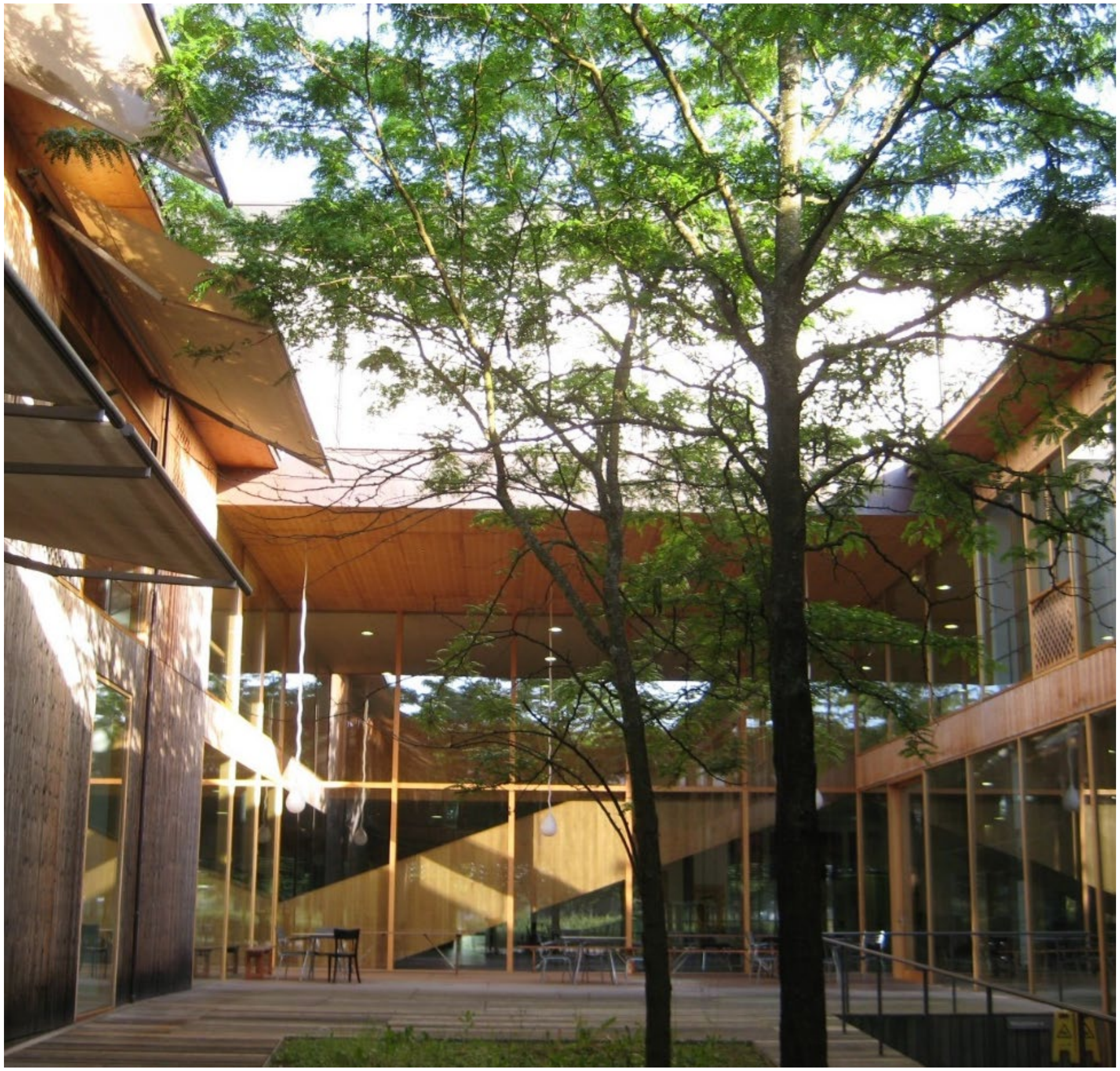


Figure 67: French Garden (Stair Beyond)

5.3 Therapy Throughout

Figure 68: Functional Approach to Occupational Therapy as Making Food

Ecologically valid approaches to rehabilitation involve doing real-world activities with functional goals in real-world settings.[158] In the sense of ecological psychology, rehabilitation is an irreducible function of person-environment systems. Therefore, all activities of a person in the rehabilitation center environment are, in effect, either clinical or functional therapy. The facility itself should be designed to afford and accommodate the broader spectrum of cognitive and physical abilities of TBI patients in areas traditionally not used for clinical therapy. For example, one functional approach to occupational therapy is making food in a realistically organized homelike kitchen (Figure 68).

In addition to movement, rehabilitation also requires stress relief and social support. In the Theory of Supportive Design, Ulrich provides evidence that social support helps patient recovery and reduction of stress. Nature views are an effective positive distraction and reduces stress.[159] Wilson's Biophilia hypothesis also supports a need for humans to connect with nature.[160] Clinical therapy areas can be improved by

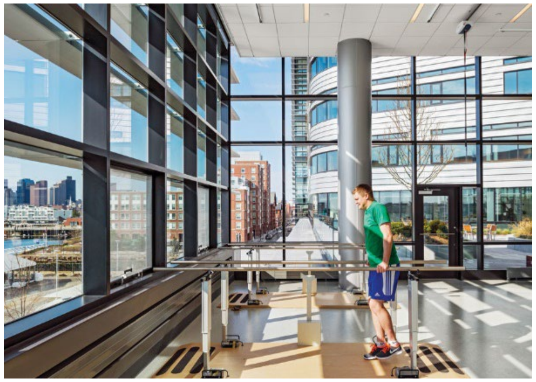


Figure 69: Therapy Gym Equipment at Spaulding Rehab facing out windows.

considering stress relief strategies through connection with nature and social support in addition to providing for technical equipment requirements. Bandura's Theory of Social learning states that people observe behavior in others and evaluate outcomes to determine whether to model the behavior [161] In accordance with this theory, seeing how others with similar (dis-)abilities use non-clinical areas successfully should facilitate patients to learn and try techniques for everyday tasks s.

The clinical therapy gym at Spaulding Rehabilitation Hospital facilitates social support and stress relief in addition to accommodating a variety of clinical therapy equipment. The therapy gym has large windows allowing expansive harbor views with pieces of equipment oriented to look out the windows (Figure 69). In accordance with anthropologist Edward Hall's research of proxemics in American culture [162], the equipment layout reflects the allowance of less intrusive social interaction between patients (4-12 feet of separation) while also providing sufficient visibility and proximity to allow for social learning and support. Sufficient space in the personal distance zone (1-4 feet away) allows for family and staff to provide more direct support (Figure 70).

Figure 70: Therapy Gym at Spaulding

Another strategy for integrating therapy throughout the facility is to improve the accessibility and therapeutic aspects of non-clinical spaces. At Basel Rehab, the entry courtyard provides not only connections to daylight from the interior, but also has an overhang which affords patient movement on an outdoor wood deck area in a setting with access to plants, daylight, and outdoor air (Figure 71). A garden plot in the center of the courtyard has been replanted multiple times with different plants (Figure 72).

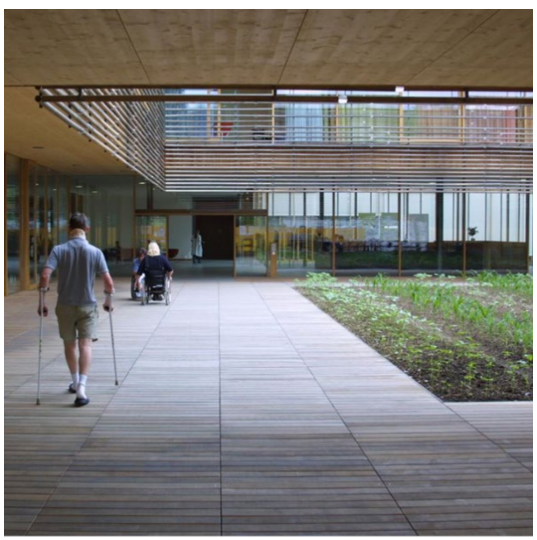


Figure 71: Basel Rehab Deck and Garden Plot

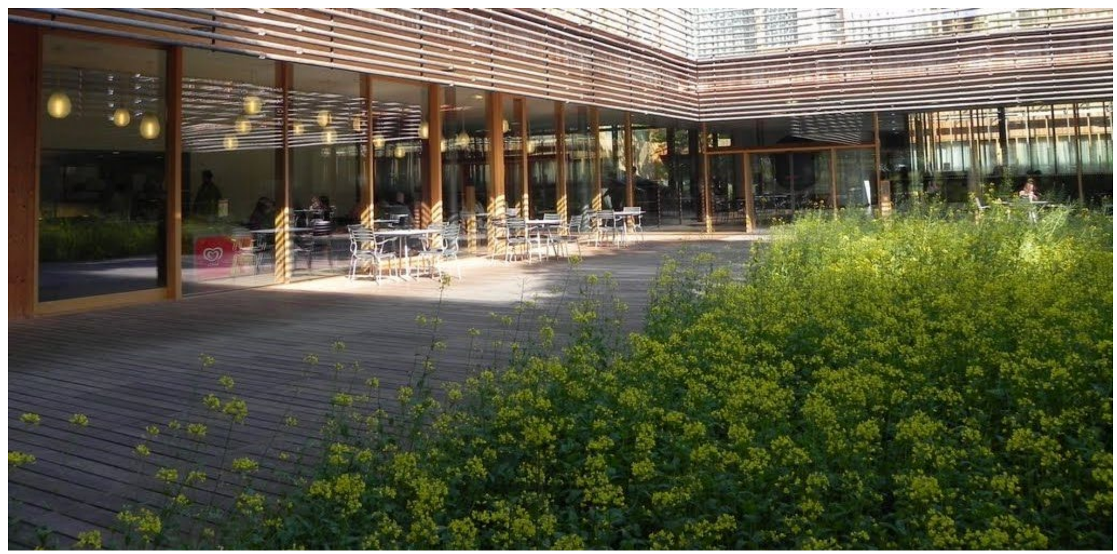


Figure 72: Basel Rehab Garden Plot with Flowers

At the Shirley Ryan Ability Lab, overhead lifts above an open stair facilitate a more functional therapeutic experience for patients to supplement the clinical therapy equipment (Figure 74). Physical and occupational therapy can occur in general non-clinical spaces, such as under a stair with the proper furnishings and support (Figure 73).


Figure 73: Therapy Under the Stair

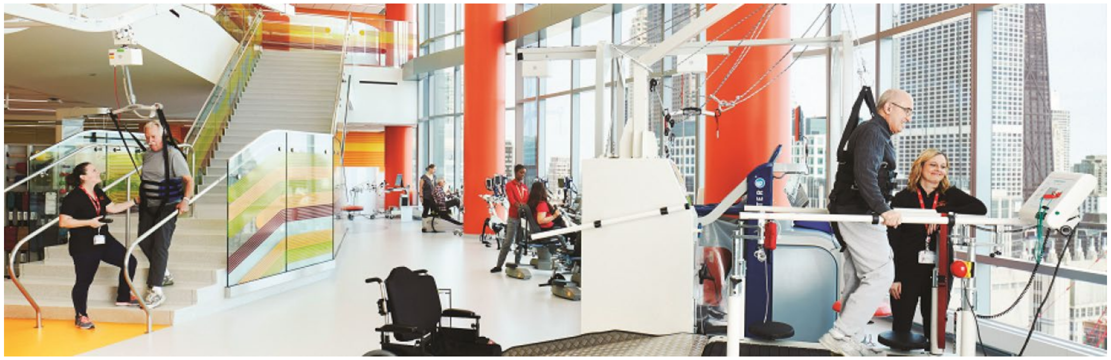


Figure 74: Therapy Gym with Open Stair

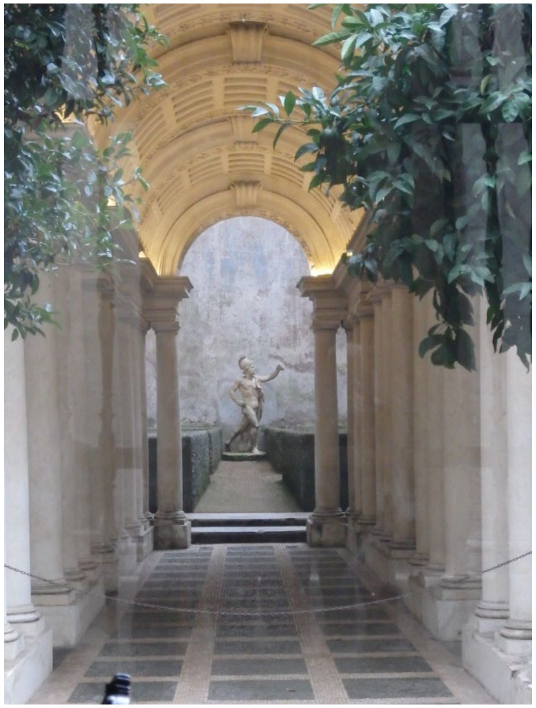


Figure 75: Gallery at Palazzo Spada

5.4 Authenticity

Ecological psychology adheres to the principle that through science, theories in physics and psychology can be reconciled.[163] The design of the built environment can elevate the expression of laws of science (such as time, place, composition) over constructed rules (style, simulation, translation). In this sense, the characteristic of the built environment that elevates truth in science can be called authenticity. Research indicates that TBI patients in rehabilitation often suffer from impairments of memory and cognition. [164] As they attune and recalibrate their bodies for perception and action (an ecological explanation of rehabilitation [165]), an authentic approach to the built environment provides supportive information that help them to more easily perceive and act within the physical and social context.

Related to the principle of direct perception and the concept of optic flow discussed earlier, design of the built environment context can assist with perception. Regularity of visual field pattern behind objects assists perceivers with object size perception.[166] There are several examples in architectural history of the manipulation of visual field

Figure 76: Gallery at Palazzo Spade with Scale Figure

pattern to create optical illusions related to distance, mass, and scale. One example is Borromini's use of forced perspective in the gallery of the Palazzo Spada (Figure 75). In the image without scale figures, the perception of scale is very different from the one with people (Figure 76). This is due to the manipulation of scaling and spacing of architectural elements to create a forced perspective.

Authenticity as principle for architecture was advocated by Frank Lloyd Wright and Louis I. Kahn in the 20th century. Frank Lloyd Wright called it "Organic Architecture":

> "…it seeks that completeness in idea in *[sic]* execution, which is absolutely true to method, true to purpose, true to character, and is as much the man who lives in it as he is himself…." [167]

Wright was also a proponent of using principle to express the nature of materials rather than architectural precedent. Principle considers the physical strengths and weaknesses of a material or technology. Precedent may overlay an aesthetic goal that is in opposition to a material's nature. For example, the architectural expression of a building made with steel would have longer structural spans with lighter materials than could ever be achieved by even the most ambitious Gothic cathedrals that were built

Figure 77: Kahn's Brick Parliament Design

with the goal of achieving light and soaring architecture but were limited by the material nature of stone that is heavy and massive by nature. [168] Louis Kahn also spoke of authenticity in architecture through concepts such as form, space, and light. One of his most well-known quotes relates to the nature of materials, which he also exemplified in work such as the 1962 Parliament building in Dhaka Bangladesh (Figure 77):

> "You say to brick, "What do you want, brick?" Brick says to you "I like an arch." If you say to brick, "Arches are expensive, and I can use a concrete lintel over an opening. What do you think of that, brick?" Brick says, "I like an arch." [169]

Their architectural philosophies inform many of the strategies that support the goal of authenticity as based in ecological approaches to psychology, design, and science. Strategies for architectural authenticity include.

- expression of invariants in optic flow through order, regularity, hierarchy, and modularity in the visual field to assist in the accurate perception of scale and distance (avoid optic illusions and assist with measuring)

- legibility of zones, departments, entrances, etc. clarity and hierarchy in form and spatial transparency (form follows function),
- reflectiveness of and responsiveness to context in time and place, such as sustainability approaches to site, water, energy, materials, and quality), health; resilience, and technology (for example, not falsely making a new building look like a historic one);
- architectural usage and expression of materials that match their nature; (for example tile that looks like a cast stone material rather than imitating a wood plank), and
- specify material colors or finishes that align with their anticipated architectural lifespan (for example, use patterns and colors in fashion for interior wall paint or chair fabrics expected to last 5-10 years, but use natural stone cladding expected to last 100 years for exterior cladding).


Figure 78: Paimio Sanatorium

The Paimio Sanatorium, built in Finland in the early 1930's, (Figure 78) designed by architect Alvar Aalto demonstrates many of the strategies aligning with the goal of

Figure 79: South Facing Terraces for Sunlight

authenticity. With the goal of architecture as a healing element and helping tuberculosis patients recover in the pre-vaccine era, the building's design reflects the health care practices of its time, which included hygiene, fresh air, and sunlight.[170]. An isolated site selection limited the potential spread of contagion. Indoor surfaces were selected to be hard, durable, and easy to keep clean. The building was laid out with a primary elongated east-west linear wing (Figure 81) to maximize patient exposure to sunlight throughout the day, including the south facing rooftop terraces (Figure 79 and Figure 80) where

Figure 80: South Facing Terraces

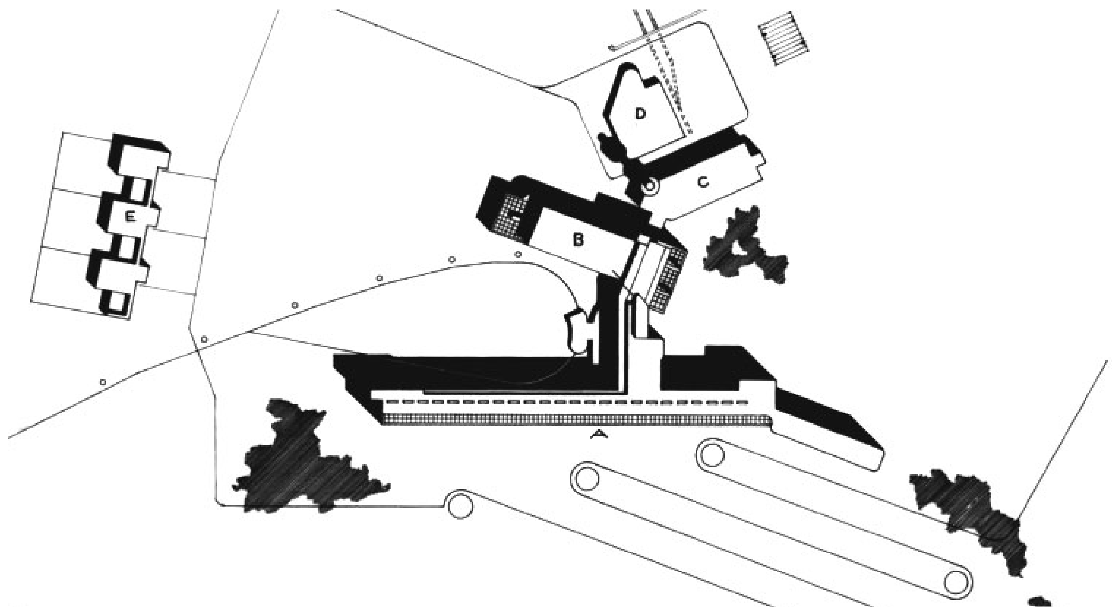


Figure 81: Paimio Sanatorium Site Plan with Shadow

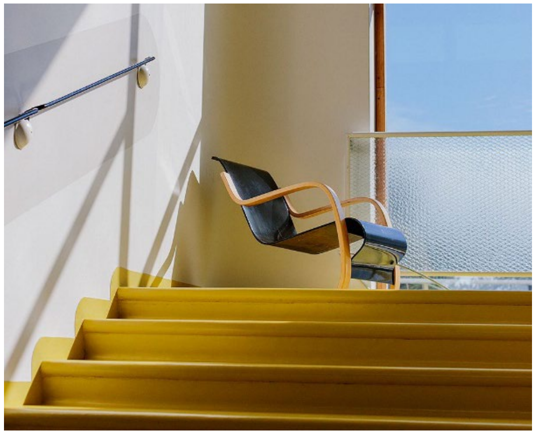


Figure 82: Yellow Flooring on Sunlit Stairs

Figure 83: Paimio Sanatorium Library

Finish material colors selected in collaboration with artist Eino Kauria were not based in fashion, but rather with specific goals to reinforce desired patient activity, such as the with darker muted ceiling paint colors in restful spaces , using different patient wing corridor colors to assist with wayfinding, and elevating patient energy levels such as with the use of a bright yellow rubber floor in activity areas (Figure 82). [172] An image of the library illustrates the custom furniture, lighting, and use of a muted green color in the ceiling with views to nature and plenty of sunlight. (Figure 83). A 2016 restoration plan documents many of the design decisions for the built environment related to health at multiple levels of scale, including site planning, building layout, finish selection, furniture, and lighting.[173]

Figure 84: Lucile Packard Children's Hospital

Figure 85: Outdoor Wood Canopy

Figure 86: Patient Room

The LEED Platinum Lucile Packard Children's Hospital Stanford Expansion in Palo Alto, CA, designed by Perkins + Will and HGA and completed in 2017, also exemplifies several of the strategies for authenticity (Figure 84). Designed to integrate a modern approach to medical technology is balanced with the goal to create an atmosphere comfortable for patients and responsive to regional context. The large facility incorporates green spaces for patient comfort and sustainable site considerations in a large rooftop garden as well as smaller window planters. Uncommon in many health care settings, several elements use real (not plastic simulated) wood salvaged from regional buildings being demolished, such as the outdoor canopy (Figure 85), elevator tower (Figure 89) and family alcove (Figure 87). The assignment of finishes in patient rooms aligns neutrality withe material permanence, using a lively purple paint for walls which likely require more frequent replacement, and neutral natural colors and materials in more permanent elements such as flooring and casework. (Figure 86). Energy efficient façade shading and daylighting responses are customized to solar orientation (Figure 88). Specific finish colors are aligned with department identity to assist with wayfinding (Figure 90).

Figure 87: Family Seating Alcove with Planter

Figure 88: South and West Facades with Responsive Solar Screening

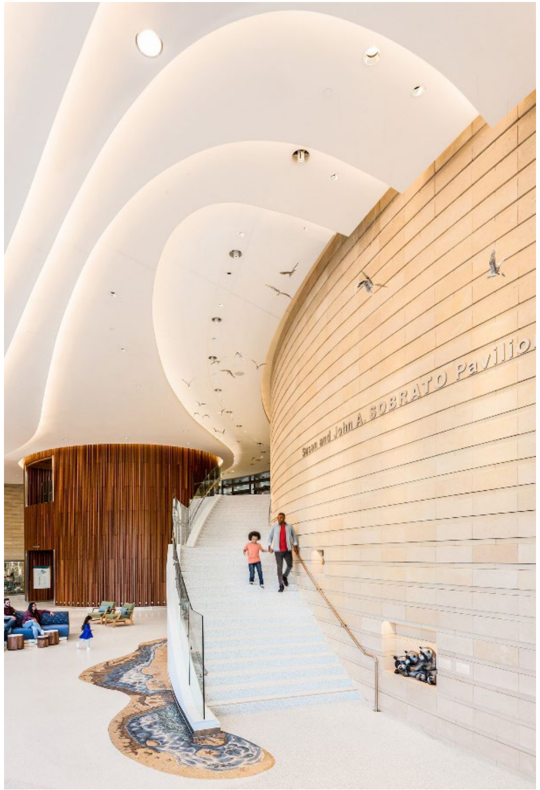


Figure 89: Reclaimed Redwood Elevator

Figure 90: Color Indicates Departments

5.5 Respite

To reduce stress, rehabilitation hospital design should provide a variety of spaces for respite that allow patients, staffs, family, and visitors to rest, observe, meditate, contemplate, destress, refocus, and recover from overstimulation. Strategies for respite occur with the incorporation of dedicated spaces in building and site planning, as well as the experiential and detailed elements of respite space materials, lighting, views, and acoustics. Calming space for TBI patients requires consideration of design for patients with heightened sensitivities to intense light and sound.[174] Wilson's biophilia hypothesis emphasizes a basic human need to connect with natural elements.[175] Attention Restoration Theory also supports interaction with nature as restorative approach.[176]


Figure 91: MUSC Shawn Jenkins Hospital for Women's and Children's Health

One example of a respite space is a porch on an upper floor outside a common dining area (Figure 91) on the upper level of the MUSC Shawn Jenkins Children's Hospital and Pearl Tourville Women's Pavilion in Charleston, SC, designed by Perkins and Will and McMillan Pazdan Smith Architecture. In an urban location, the facility strategically utilizes recesses in the upper levels of the building mass as well as rooftop gardens on lower volumes to incorporate spaces where patients can interact with nature and engage in relaxing activities, such as using a swing (Figure 92). Interior spaces provide respite as well, with nature views and soothing colors in the "lantern lounges" used for respite in the patient units (Figure 93).

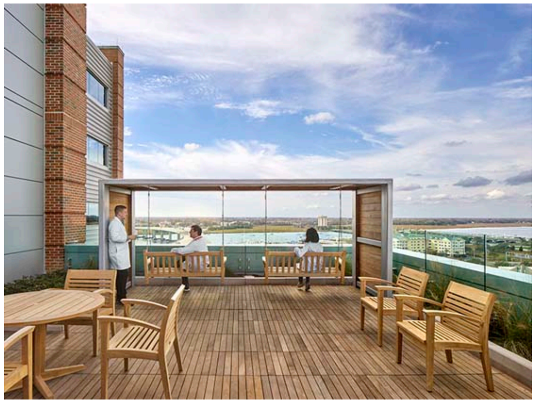


Figure 92: Rooftop Swing

Spaulding Rehabilitation Hospital in Boston designed by Perkins + Will provides a green respite space accessible to patients and staff on upper building levels on an urban site through a rooftop café with plantings that overlooks Boston Harbor (Figure 94).

Figure 93: Lantern Lounge

Figure 94: Rooftop Space at Spaulding Rehabilitation Hospital

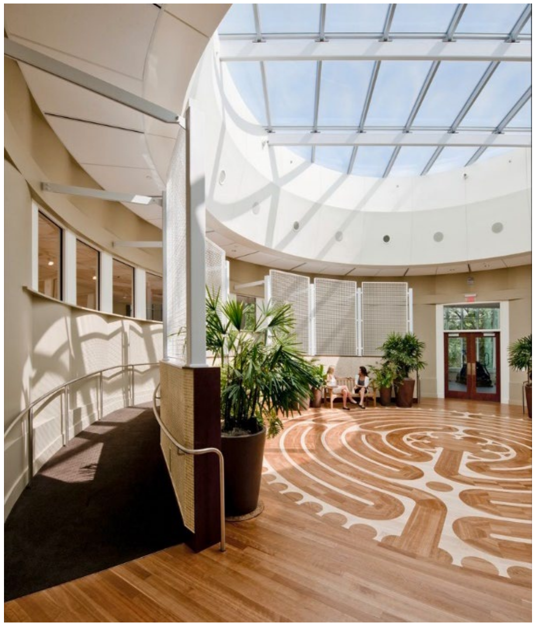


Figure 95: NICoE Central Park

Figure 96: NICoE Lobby

The National Intrepid Center of Excellence in Bethesda, MD, designed by Smith Group JJR, demonstrates strategies for incorporating respite spaces at the interior of the building as well. On the second level of the rehabilitation facility is a space referred to as "Central Park" (Figure 95), a skylit space with a meditation labyrinth etched into the wood floor. The space also includes comfortable seating, natural plantings, and variety of natural material finishes. In her book, Healing Spaces, Esther Sternberg dedicates a chapter to the healing potential of labyrinths and mazes which facilitate meditation and positive distraction from stress.[177] In this space and others at the NICoE, particular attention was paid to the control of lighting and glare, with lighting sources being indirect in most areas in recognition of the sensitivity of TBI patients to glare. The central lobby space (Figure 96) incorporates comfortable seating, indirect lighting, and multiple scales of space which allow building users to choose between more exposed seating options or more protected for those sensitive to being exposed (Figure 98) , particularly those with military training. [178] The NICoE also integrates art through an overhead bird sculpture in the front entry lobby (Figure 97)

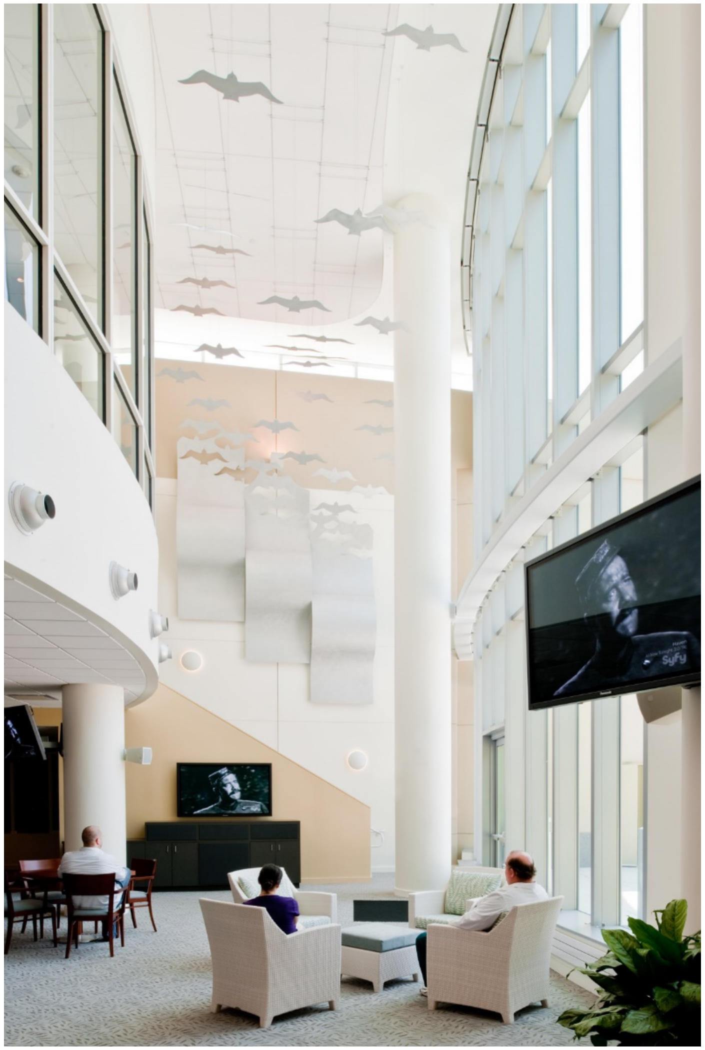


Figure 97: NICoE Entry Lobby

Figure 98: NICoE Seating Area

5.6 Multisensory Simulation

Designers should propose a variety of building spaces, materials, systems, and fenestration which afford patient exposure to a variety of environments that also allow for control of view, light, sound, and air quality. Create spaces where patients, family and staff can open the windows and shades to illuminate interior spaces with daylight, to feel the warmth of sunlight, to see the sky, to see views of nature, to see activity, to feel the outdoor air, and to hear sounds from outside. A critical part of multisensory design also includes responsiveness to diverse levels of ability and sensitivity through the ability to control stimulation.[179]

TBI patients often suffer from memory loss and confusion about their identity and preferences.[180] Rehabilitation for TBI is a time when some patients initially discover changes in their ability to see, hear, feel, taste, and smell, among other effects. Recall the experience shared by Trisha Meili who discovered during an occupational therapy session that she was unable to smell the cookies they were making.[181]. Averill's Control Theory states that control over environmental stimuli reduces stress for patients and

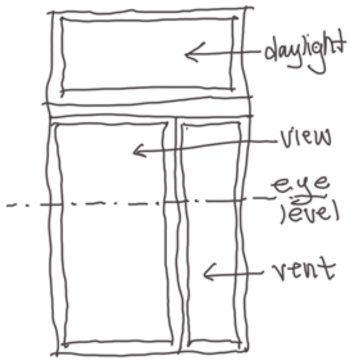


Figure 99: Window Function Zones

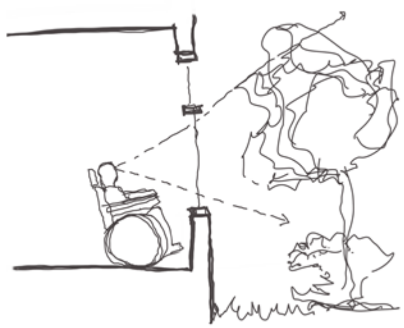


Figure 100: Window Placement for Lower Sightlines

families.[182] Ulrich's Theory of Supportive Design also clarifies that stress reduction through control of one's environment can come from the ability to control a stimulus (such as turning off lights), or the ability to escape the stimulus by relocating to a different place.[183 184]

Strategies for multisensory stimulation can be incorporated at the facility planning level through the coordination of building space locations with contextual opportunities for stimulation such as light quality, functional adjacencies, and distant views. Experiential design considerations include variations in the scale of space through room sizes and heights, access to larger space from multiple level viewpoints, and opportunities to move through spaces in a variety of modes such as stairs, elevators, ramps, and others. Design of the room experience for users in wheelchairs requires special consideration, such as making windowsills at a lower level to allow visibility of foreground zones closer to the façade (Figure 100). At a more detailed level, design of façade elements such as louvers, shades, and screens and controls for doors and windows offer many health benefits in terms of view, daylighting, and circadian stimulus. [185] Operable windows add


Figure 101: Spaulding Rehabilitation Hospital Patient Room


Figure 102: Operable Windows

value in terms of controlling acoustical, fresh air and thermal characteristics which can provide positive distractions to reduce stress, but the design of these requires more careful consideration of functional zones (Figure 99).

Spaulding Rehabilitation Hospital is designed with screened operable windows throughout the facility, including patient rooms (Figure 101), lobbies (Figure 104), and therapy areas (Figure 69), not only for passive survivability in case of sheltering in place during power loss, but also to provide control for building users to allow more variable air quality conditions as well as sounds from the harbor.[186] Some Boston residents may come from homes without air conditioning and have a different or broader zone of comfort in terms of heat and humidity. The windows are lockable by staff to prevent opening at times when it would be detrimental (such as too hot or freezing). Patient room windows (Figure 101) have a sill height of 24” above floor level for increased visibility and with clerestory zones for improved daylighting. Accessible green roof areas provide pleasant variable experiences views from multiple floor levels (Figure 103).

Figure 103: Green Roofs and Gardens

Figure 104: Upper-Level Lobby at Roof Terrace

Figure 105: Corner Windows with Louvers

Figure 106: Pool


Figure 107: Live Oak Bench

Spaulding Rehab offers a variety of spatial experiences from a blue-green pool area with a sinuous ceiling form (Figure 106) to corner widows with strong linear exterior louvers that modulate the scale as well as helping to control glare (Figure 105) Natural wood furniture pieces provide visual and tactile stimulation. These benches (Figure 107) were made from live oak tree logs from historic shipbuilding found during excavation for the hospital. The overhanging back piece designates a zone of space for a wheelchair user to sit next to someone on the bench. [187]

6 PROJECT DEFINITION AND PROGRAM

The Comprehensive Inpatient Rehabilitation Hospital is a facility type well-suited for the study of design guidelines that serve patients with traumatic brain injury because they are dedicated facilities for holistic TBI therapy where patients live and work within the same environment day and night, for weeks or months at a time. The program for this thesis is adapted from a program provided by an expert in architectural design of TBI rehabilitation facilities, Brenna Costello of Smith Group JJR. The size of the program reasonably relates to the scale of the emerging regional rehabilitation hospital typology, one of which was recently announced in the proposed project city, Knoxville, TN. More regional locations rather than fewer larger national locations for rehabilitation hospitals helps to reduce patient isolation and increase family support because family and friends do not have to travel as far to visit the facility.

Program Summary

	DEPARTMENT/ ROOM	Net SF	Grossing Factor	Dept. Gross SF	Subtotal
PUBLIC /OUTPATIENT SUPPORT		**6,352**	**1.11**		**7,030**
1	LOBBY / PUBLIC	3732	1.08	4031	
2	ADMISSIONS	900	1.25	1125	
3	GIFT SHOP	470	1.08	508	
4	PASTORAL CARE	470	1.08	508	
5	CONFERENCE / MEETING	780	1.10	858	
PATIENT CARE UNITS		**33,664**	**1.50**		**50,496**
7	TBI ACUTE NURSING UNIT (16 bed)	14,000	1.50	21,000	
8	SCI ACUTE CARE UNIT (16 bed)	13,640	1.50	20,460	
10	TBI TRANSITIONAL NURSING (4)	2,938	1.50	4,407	
11	SCI TRANSITIONAL NURSING (4)	3,086	1.50	4,629	
THERAPY & CLINICAL SUPPORT		**28,104**	**1.21**		**33,868**
12	THERAPEUTIC RECREATION	2,628	1.04	2,736	
13	SPEECH THERAPY	1,580	1.30	2,054	
15	OCCUPATIONAL THERAPY	1,360	1.35	1,836	
16	GYM / POOL / RE-EVAL	9,250	1.15	10,638	
17	PAT. & FAM. EDUCATION	700	1.15	805	
18	PAT. & FAM. SERVICES	1,200	1.30	1,560	
19	PHARMACY	2,636	1.15	3,031	
20	OUTPATIENT SERVICES	2,870	1.35	3,875	
21	CLINIC / PROCEDURES	1,790	1.40	2,506	
22	PSYCHOLOGY	680	1.25	850	
23	IMAGING	0	1.20	0	
24	LAB	440	1.08	475	

25	RESPIRATORY THERAPY	680	1.35	918	
26	SLEEP LAB	0	1.25	0	
27	TELEHEALTH/NURSE ADVICE	430	1.25	538	
28	WHEELCHAIR CLINIC	1,860	1.10	2,046	
ADMINISTRATIVE SUPPORT		**4,960**	**1.25**		**6,180**
29	ADMINISTRATION	640	1.25	800	
30	FOUNDATION	0	1.25	0	
31	MARKETING	0	1.25	0	
32	BUSINESS	960	1.25	1,200	
33	INFECTION CONTROL	120	1.08	130	
34	DIETICIANS	140	1.25	175	
35	VOLUNTEERS	0	1.08	0	
36	HUMAN RESOURCES	820	1.25	1,025	
37	HEALTH INFO MANAGEMENT	480	1.25	600	
38	FOLLOW-UP SERVICES	720	1.25	900	
39	RESEARCH	0	1.40	0	
43	NURSING EDUCATION	1,080	1.25	1,350	
FACILITY SUPPORT		**11,745**	**1.14**		**13,397**
46	INFORMATION TECHNOLOGY	1,750	1.20	2,100	
47	MEDIA SERVICES	0	1.25	0	
48	CULINARY	2,210	1.25	2,763	
49	DINING	2,130	1.10	2,343	
50	FACILITIES	840	1.10	924	
51	ENVIRONMENTAL SERVICES	640	1.20	768	
52	MATERIALS / CENTRAL SUPPLY	2,160	1.15	2,484	
53	MECHANICAL/ELEC./PLUMBING	2,015	1.00	2,015	

BUILDING TOTALS	
TOTAL DEPT. NET SQUARE FOOTAGE	169,650
AVERAGE DEPT. GROSSING FACTOR	0.65
TOTAL DEPT. GROSS SQUARE FOOTAGE	110,97 1
BUILDING GROSSING FACTOR	1.2
TOTAL BUILDING GROSS SQUARE FEET	133,165

Key Programmatic Considerations. The prototypical program provided was also modified as informed by the thesis design guidelines as follows. The design guideline of community interaction has the greatest impact on proposed modifications to the program in terms of areas and adjacencies.

In order to facilitate community interaction, a new café area is proposed where the public can interact with patients. Additionally, the area of public lobbies is expanded to allow for a zone of space where patients and the community interact as they are going about their daily routines. In order to build a more memorable narrative of rehabilitation, the building and all spaces should be designed with sustainable design performance criteria using the LEED rating system as a guide. On the patient floors, the spaces for family and activities of daily living are combined and distributed into several areas to allow for smaller scales of interaction rather than one large space.

To encourage movement and distribute therapy throughout, the allocation of area for public lobby space is increased to allow space for therapy activities that do not require the use of immovable equipment. Guidelines related to authenticity affect the program in terms of alignment of programmed spaces that respond to context. In other words, the analysis of the site may indicate an opportunity for program elements unanticipated in a prototype such as spaces for community events and activities. While places for respite are addressed as allocated areas in the program such as family areas and chapels. Outdoor spaces are not programmed in the prototype but desired and will likely be added as the building design develops in areas such as low roof terraces. Multisensory stimulation also reinforces the judicious use of space prototypically included in the grossing factor and affects more detailed room requirements.

7 SITE SELECTION AND ANALYSIS

In the ecological approach to rehabilitation, every design guideline affects the site selection and analysis. To facilitate community interaction, the site is best located in a mixed-use community with a diverse and active public realm. Locating facilities at a regional level facilitates community interaction better than fewer larger facilities at a national level. Site can encourage movement through the walkability of the site and its surrounding area. Therapy throughout the building can be assisted if the site offers some inherent challenges related to activity that can be studied in multiple ways. Authenticity at the level of site has to do with the ability of the site to support a sustainable design approach. Through the reinforcement of a narrative of healing, the selected site should build community pride and character while also being more noticeable and memorable. Site can offer places for respite, but this must be carefully balanced with community interaction. Remote sites with natural beauty may offer respite, but undermine attempts at community interaction, so respite may be best created within the site and at the building level. A better site might have an adjacency or sufficient area to develop to an amenity for respite such as a park, trail, or waterway. Multisensory stimulation should be supported by a variety of conditions in and around the site in terms of exposure to elements of nature (sun, wind, water, earth, and other living organisms such as birds, animals, and people). Another consideration for multisensory stimulation is variety in scale of viewshed. A site that offers distant views as well as a rich neighborhood scale experience provides more sensory diversity.

Site Selection. The site selected to study the ecological approach to TBI rehabilitation is in the regional mid-sized city of Knoxville, TN. Supporting the alignment of program and location is the recent announcement by two different health care systems that each plan to develop rehabilitation hospitals in the area within the next five years. The site selected follows the model that many health care systems choose, which is to build the project in an existing health campus neighborhood to allow for shared support infrastructure and resources. Figure 108 illustrates the site context in a mixed use walkable medical district adjacent the flagship state university campus.

Figure 108: Site Context

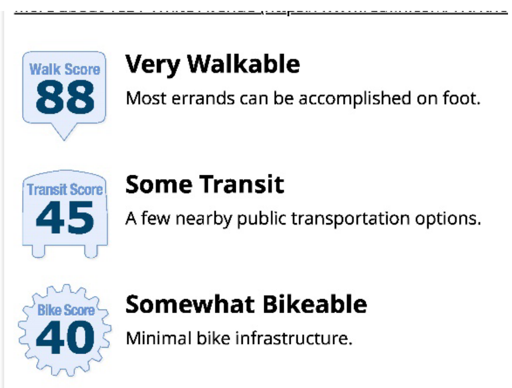


Figure 109: Neighborhood Access Ratings

As indicated in Figure 110, access to the site is multi-modal, though personal vehicle is the primary form of transportation in the area. The hospital has constructed numerous parking garages north and west of the site. Clinch Avenue and Cumberland are served by multiple stops for the regional bus network. Metrics from “Walkscore” (Figure 109) indicate a site that is very walkable, has some transit and minimal bike infrastructure, though a popular greenway trail for biking is located less than half a mile from the site.

The particular site within the district is currently a blighted property in the form of a surface parking lot for hospital staff at the intersection of the large scale institutional medical district zone and the adjacent neighborhood conservation district with historic single-family residences largely in use as professional offices or divided into multifamily dwellings usually inhabited by students. The site is located between the main acute care hospital facility and an active commercial district with shops, restaurants and housing centered along the east-west street of Cumberland Avenue, called “the strip”.

Figure 102 is a visual representation of this neighborhood analysis. Figure 111 gives a bird’s eye view of the area immediately around the site.

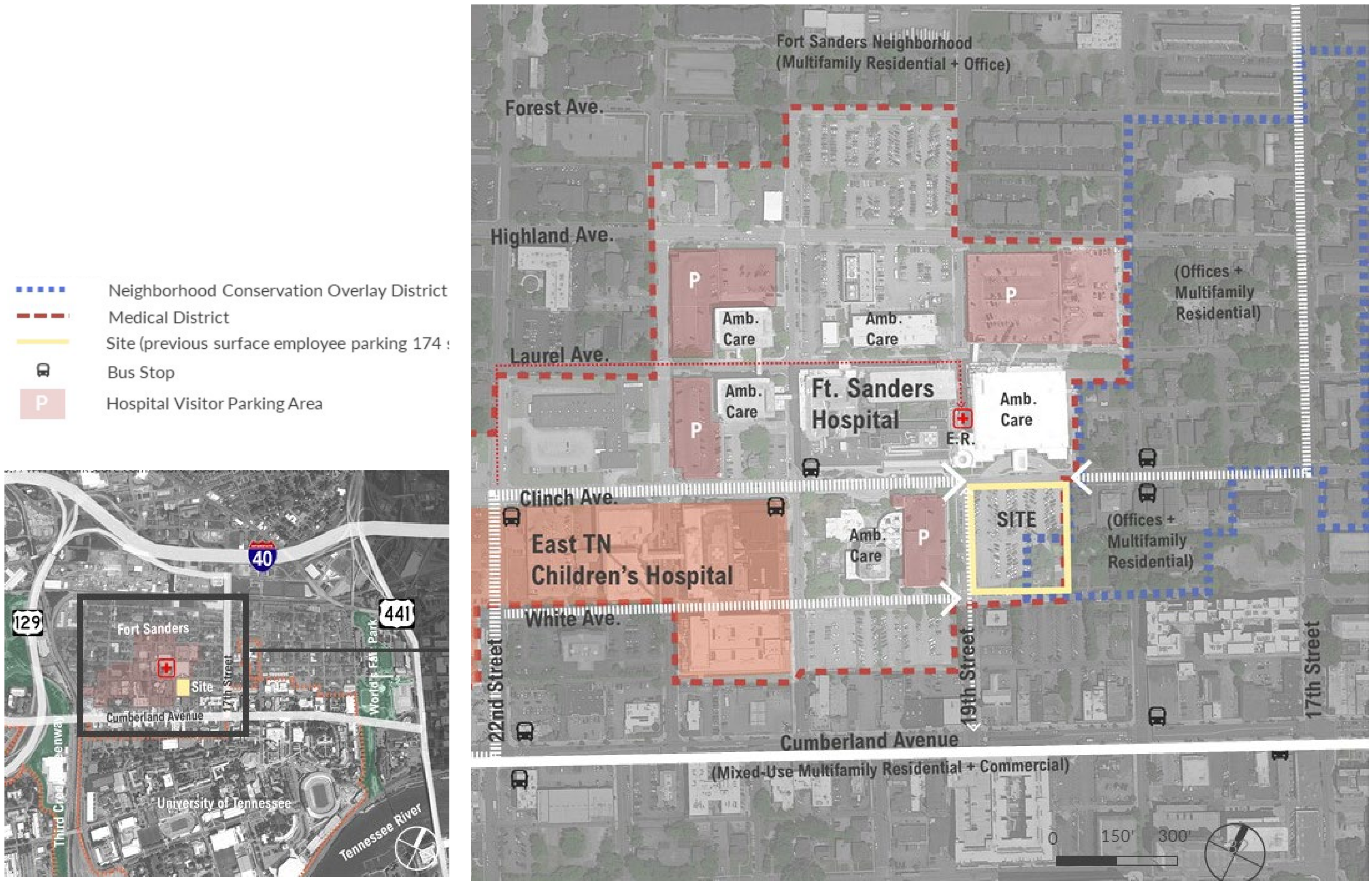


Figure 110: Neighborhood Analysis

Figure 111: Birds Eye View from SW

Figure 113: Birds Eye View from Northwest

The site is located on a steep south facing slope that is too steep even for electric wheelchairs to navigate. Figure 113 illustrates the sectional condition with a grade change of 42 feet vertically (3-4 stories tall). Nineteenth Street, on the west side of the property is a popular pedestrian thoroughfare between the acute care hospital to the north and Cumberland Avenue to the south. These conditions offer distant views of the mountains to the south (Figure 112) and desirable southern solar exposure which will provide a variety of lighting conditions for multisensory stimulation as illustrated in the solar exposure analysis (Figure 114). As indicated on the site plan, there are sidewalks on 3 sides and an alley right of way to the northeast (Figure 115)

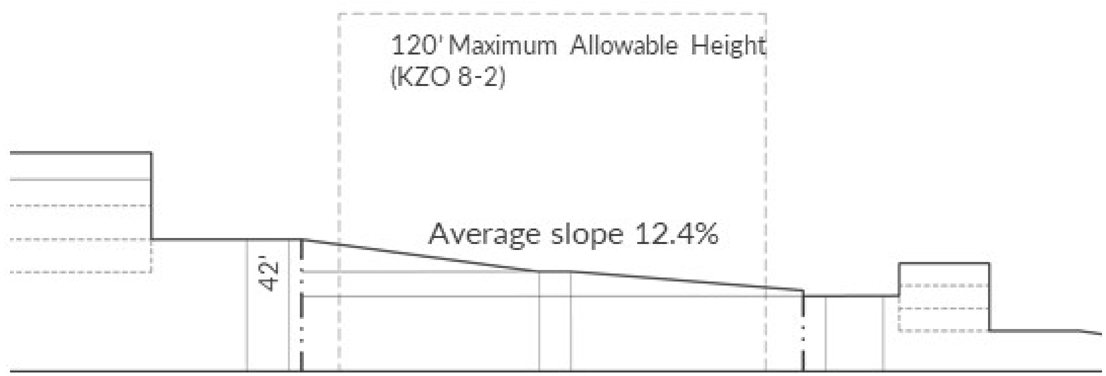


Figure 112: Site Section Looking East

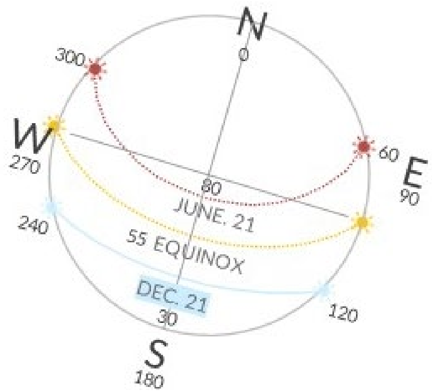


Figure 114: Solar Exposure

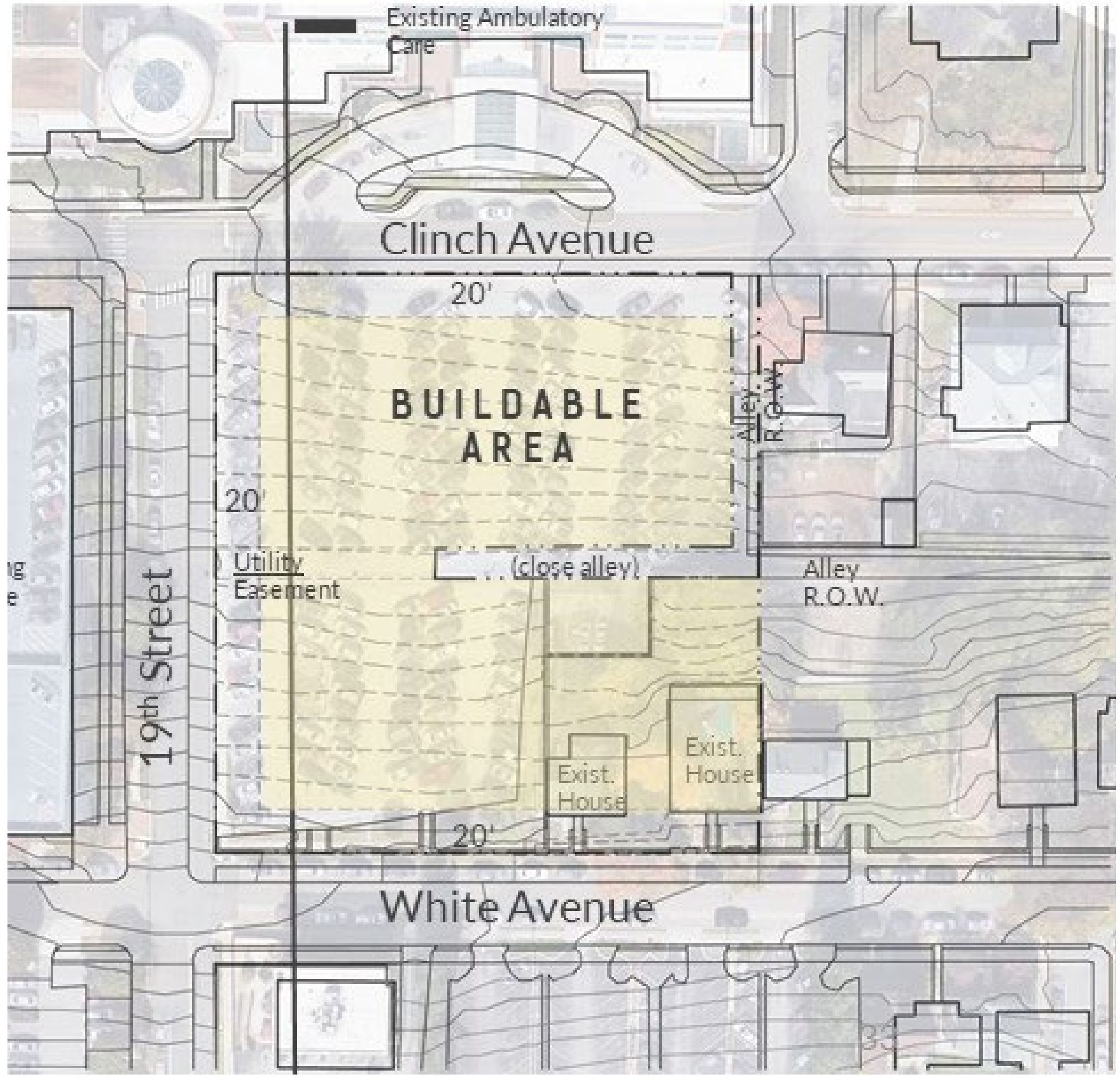


Figure 115: Existing Site Plan

8 PROPOSAL

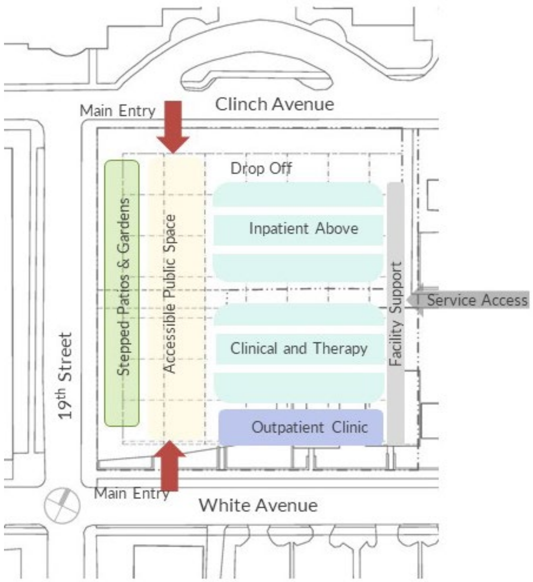


Figure 116: Site Plan Parti Diagram

Consideration of the opportunities and constraints point to a few big picture design responses which exemplify design guidelines in an ecological approach to rehabilitation. An overlay of the site and program with design guidelines generated a few major strategic design moves, as graphically illustrated in Figure 116.

- A major accessible public space adjacent to 19th Street creates supports interaction of building users and the community walkers by offering varying modes of movement uphill and providing public outreach program components. Entrances to the north, south and west engage the major street frontages and likely points of entry from neighboring parking and transit.

- Adjacency to the institutional district aligns with taller massing and more program area on the north side of the site. Outpatient functions at a lower scale with outpatient and administrative functions allow for more architectural openness to engage and activate the neighborhood along White Avenue (Figure 117).
- Utilizing the slope, much of the building parking is integrated into a below grade garage, allowing human-occupied program spaces to activate street frontages.

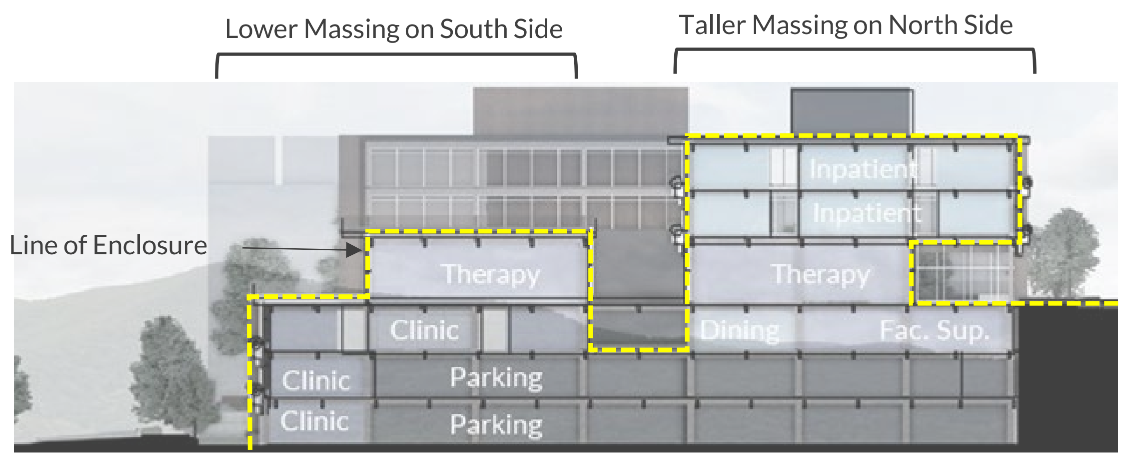


Figure 117: Site Section Diagram Facing West

- Distribute facility support services along the alley on the east side of the site to provide orderly parallel service to east-west oriented program departments, optimized in that orientation for controlled solar exposure.

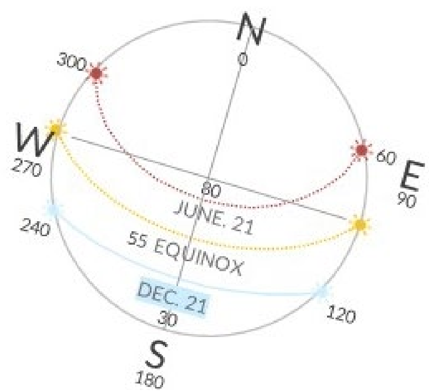


Figure 118: Sun Path

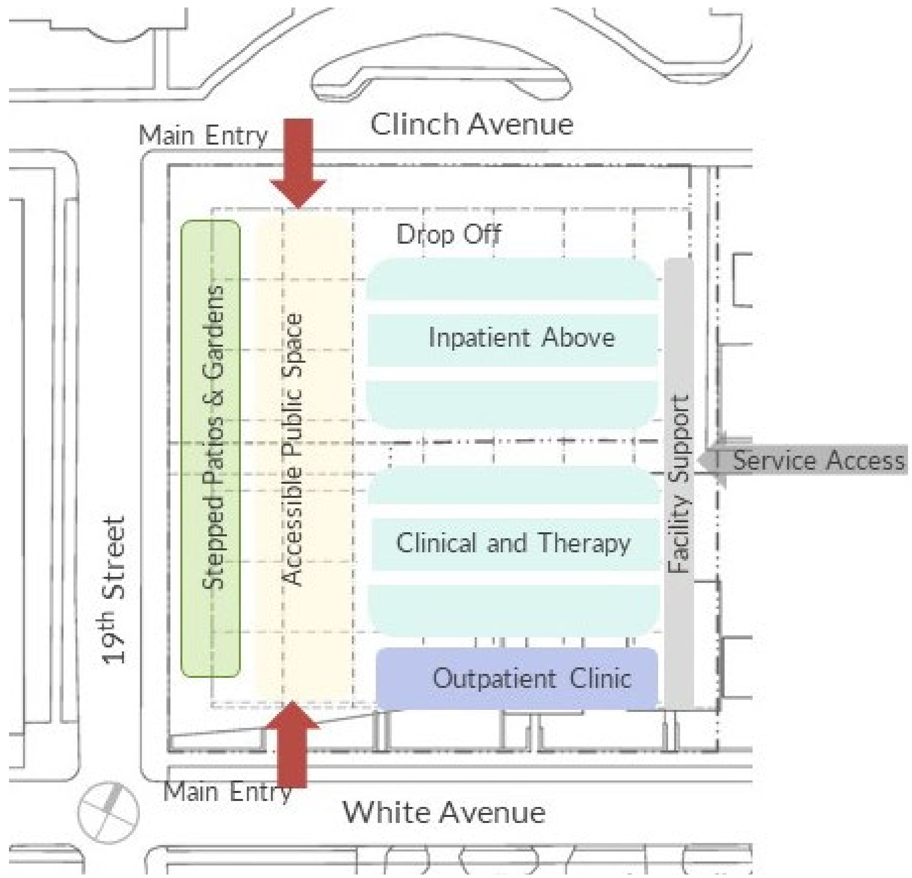


Figure 119: Site Concept Plan

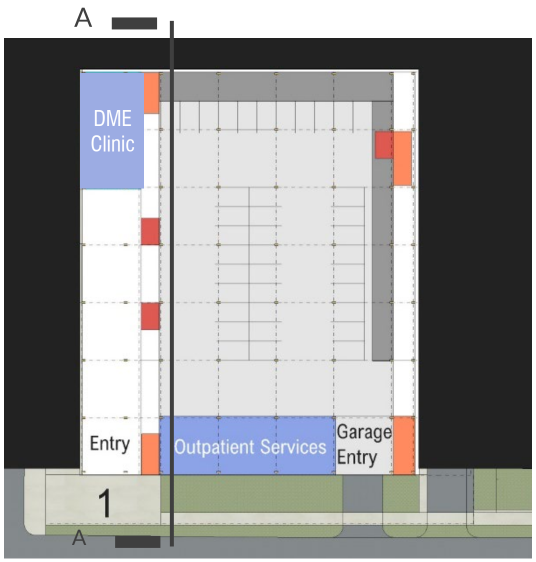


Figure 120: Level 1 Plan Diagram

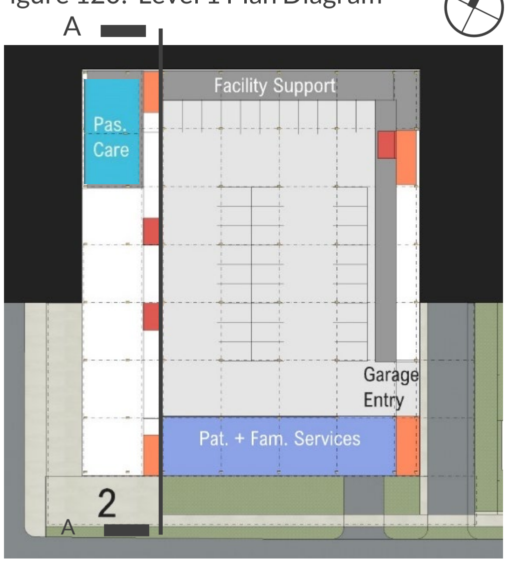


Figure 121: Level 2 Plan Diagram

Program Distribution. Consistent with the primary goals of the project, the figures at left indicate the basic layout of the program on six levels. The lowest levels (Figure 120 and Figure 121) contain below-grade parking and facility support areas on the north side of the building. Outpatient services are on Level 1, on grade with White Avenue to the south and helps to provide "eyes on the street" since most of these program activities are offices and meeting rooms which allow visual openness and may potentially be utilized by more able-bodied patients and families that may use transit or park remotely in the neighborhood. Level 2 is laid out similarly to Level 1 with outpatient services with slightly more private functions. The entrance to public parking faces White Avenue to the south. The entrance to staff parking on level 2 is from the alley to the east. Figure 122 clarifies that Levels 1-3 are below grade to the north.

Figure 122: Section AA Facing West

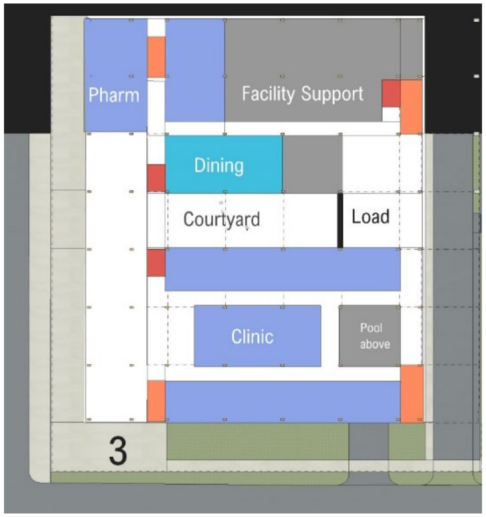


Figure 123: Level 3 Plan Diagram

Level 3 is on grade with the alley that continues along the block to the east. It provides on-grade access to the service loading dock and facility support under the north wing. Level 3 also has on-grade connections to the sloping sidewalk along 19th Street on the West side of the facility (discussed more later). A dining courtyard (separates the massing of the north and south wings and adjoins the 3rd floor dining room. A fountain dominates the end of the courtyard and provides acoustic as well as visual buffering from the facility support areas to the east.

Figure 124: Dining Courtyard View from Atrium

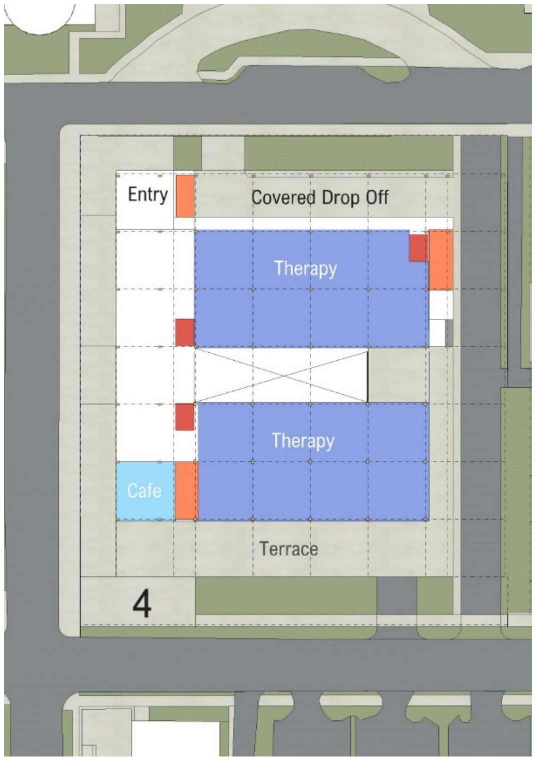


Figure 126: Level 4 Plan Diagram

Covered Drop Off. Level 4 (Figure 125) is on-grade with Clinch Avenue to the North. The covered drop off (Figure 126) at Clinch Avenue is pushed south into the north wing at level 4 and is sheltered by the upper floors This provides a safer and higher quality of pedestrian experience which encourages movement around the building and improves its likelihood for engagement as outdoor therapy activity space. It terminates in the alley to the east where drivers return north to Clinch Avenue, or south to White Avenue and parking.

Figure 125: North Façade

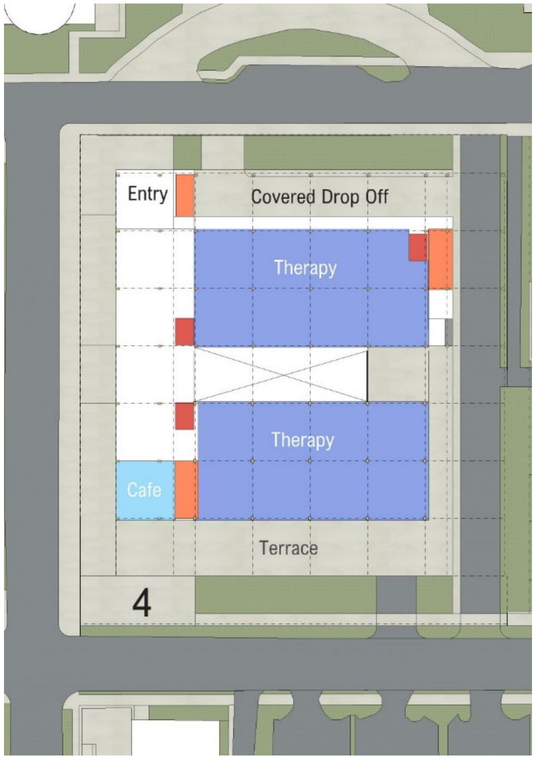


Figure 127: Level 4 Plan Diagram

Main Hospital Entry. At the northwest corner on grade with Clinch Avenue is the primary entrance to the facility from the rest of the hospital campus and faces the most common area of approach to the facility the northwest. A covered entrance invites pedestrians to enter the north end of the atrium space, while the vehicular covered drop off to the east beyond recedes to reinforce the character of the district as walkable and inviting to the community.

Figure 128: Northwest Entry

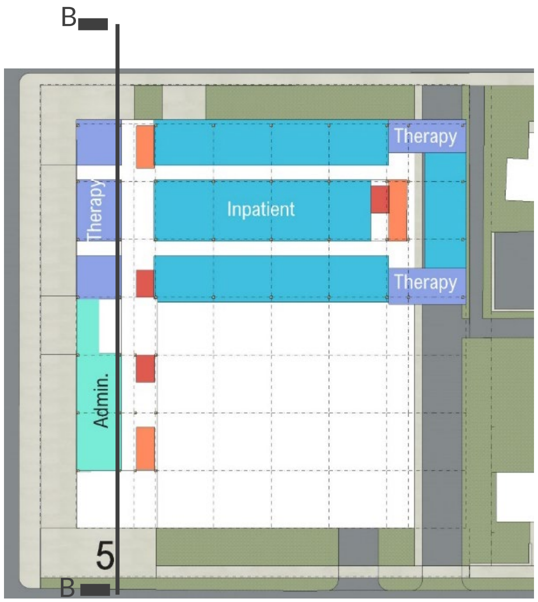


Figure 129: Levels 5+6 Plan Diagram

Inpatient floors. Levels 5 and 6 (Figure 129) are nearly identical inpatient floors which require more isolation for security reasons, but still need visual connection to the neighborhood. These levels are primarily on the north side of the site with no on-grade access as provided for other program areas more utilized by outpatients and the public.. Seciton BB through the atrium (Figure 130) clarifies the relationship of levels 5 and 6 as above all surrounding grade levels and close to level with the existing hosptial parking garage west of 19th Street beyond. This allows the patient rooms and inpatient therapy spaces to overlook the rest of the site and lower neighborhood to the east.

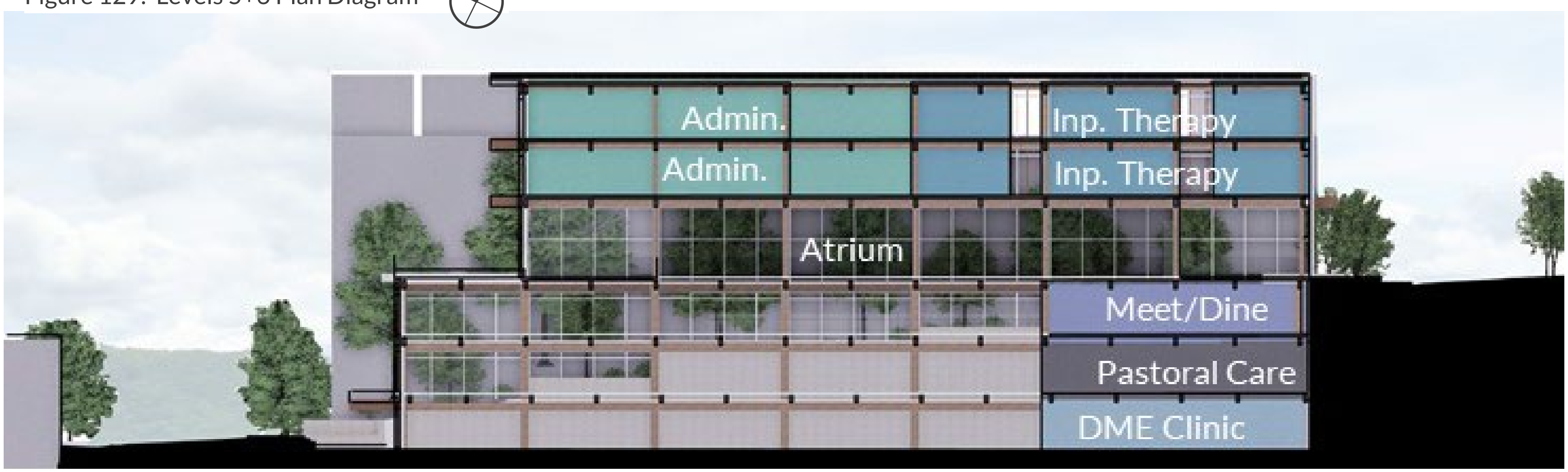


Figure 130: Section BB Facing West

Sustainable design. The exterior design of the façade and massing reinforces community interaction through a transparent solar wall on the west facing active program spaces along 19th Street. Green roofs with solar panels (Figure 131 and Figure 133) mitigate the urban heat island effect, slow rainwater runoff, and offset facility energy usage (Figure 131).

Figure 131 Solar Green Roof

Figure 133: Transparent Patterned Solar Panels

Figure 132: Exterior from Southwest


Figure 134: Transparent Patterned Solar Panels


Figure 135: Crab Orchard Stone Color + Coursing

A screen of sun tracking operable semi-transparent solar panels (Figure 134) on the south and west façades (Figure 136) mitigate glare and radiant heat from southwestern sun while also increasing the area of the building dedicated to active energy production. Stepped outdoor patio areas along the 19th Street slope (Figure 137) provide additional zones of interaction, buffered by grade offsets and plantings for a gradient of privacy. Regional exterior and interior materials of Tennessee Crab Orchard stone reinforce the authenticity of time and place (Figure 135).

Solar Panel Screen

Stone Veneer

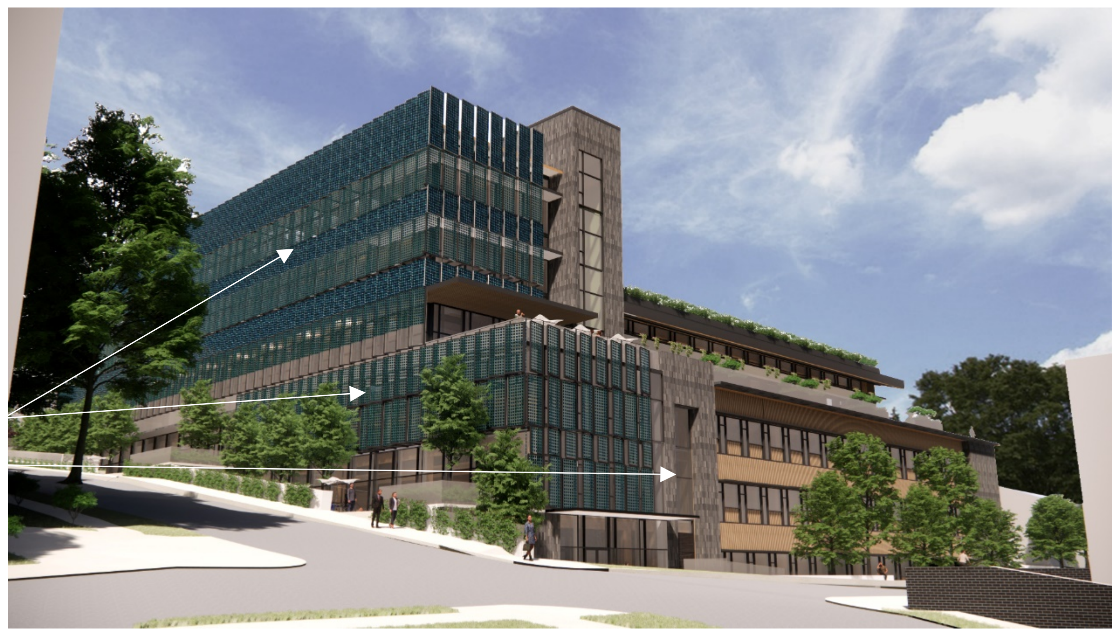


Figure 136: South and West Facades (View from 19th Street and White Avenue)

Figure 137: Stepped Patio Areas Outside Along 19th Street

Figure 139: Cladding Example

Wood veneer phenolic core siding planks also reinforce the regional material palette. Parking garage access is primarily from the south and east with the intent to minimize disruption of pedestrian infrastructure and neighborhood scale related to movement, therapy, and multisensory experience. Overall, the sustainable design approach reinforces a more memorable narrative of healing and rehabilitation for a formerly blighted site (Figure 139).

Figure 138: South Facade (White Avenue)

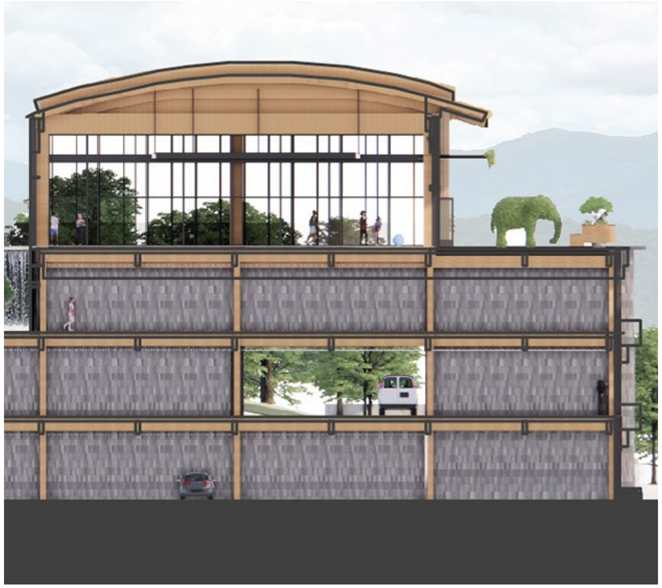


Figure 140: Therapy Gym Section

Therapy. The clinical therapy spaces are designed to connect to the atrium at the Clinch Avenue on grade level four (Figure 143). The therapy gym has a curving wood lamella roof form that contrasts with the orthogonal nature of the rest of the facility (Figure 140, Figure 141, and Figure 142). The roof structure also supports an overhead track to enable flexible use of overhead lifts in therapy. Both the therapy gym and pool space open up to a rooftop fitness terrace on the south side of the facility, with distant views of the mountains.

Figure 141: Building Section Facing East Through Therapy Gym

Figure 142: Therapy Gym with Fitness Terrace Outside

Figure 143: Level 4 floor Plan (On grade with Clinch Avenue to North)

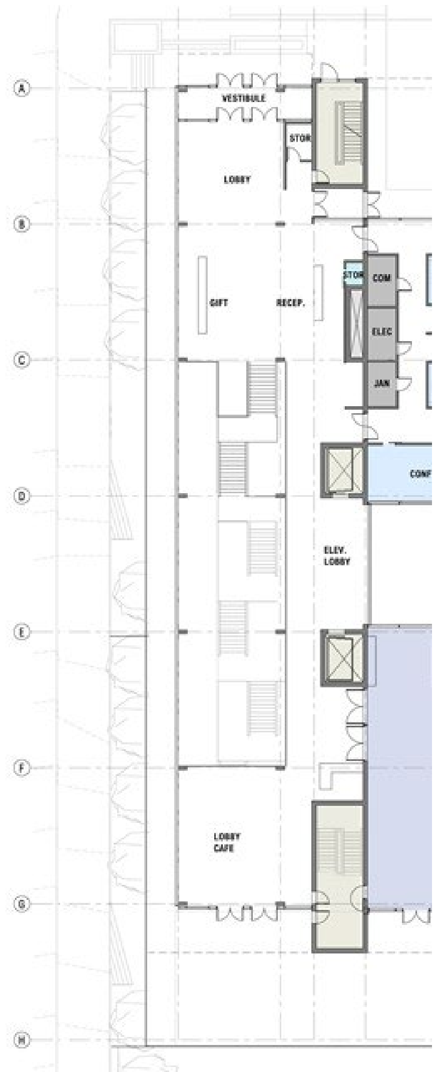


Figure 144: Level 4 Atrium Plan

Public Circulation Atrium. The major atrium space along 19th Street facilitates shared space interaction for everyday use by the community and building users by connecting all public areas of the interior and exterior of the facility. The major entry points of the atrium engage with the most public levels of the facility program at levels 1 and 4 (Figure 144). The atrium is designed for multisensory experience in terms of scale, material, mode of movement and light. An eye-catching incline lift allows disabled users to experience movement up and down the site slope in a spatially similar fashion as more able-bodied users (Figure 145). The central stair provides functional physical therapy alternatives and is broken up into sections which provide an orderly breakdown of scale of the four levels connected, reinforcing authenticity of direct perception of the space (Figure 146). The exposed laminated wood structure also reinforces the modularity of the space, accentuates the sustainable design approach, and enriches the sensory experience with visual and tactile variation. The open space also helps with wayfinding as visitors can see all the public levels looking over the balcony rail from the main entry (Figure 147).

Figure 145: Atrium View from Level 1 South Entry with Incline Lift and Stair

Figure 146: Section Axon of Atrium Facing West at Stair

Figure 147: Atrium View from North Entry

Figure 148: Clay Creative Glulam Wood Beams

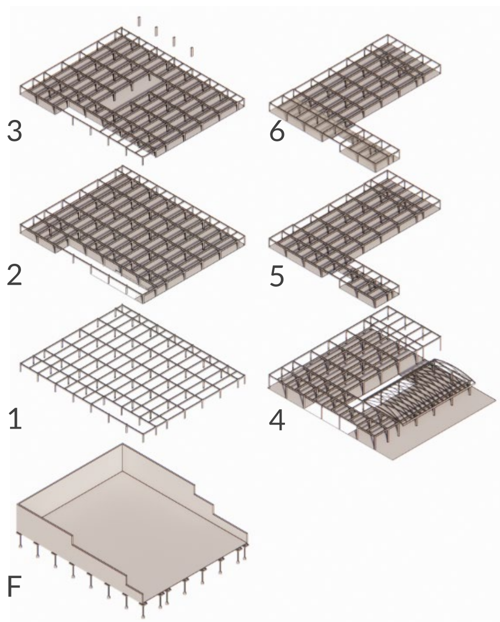


Figure 149: Proposed Project Structure Diagram

Construction. To create a more regionally authentic and sustainable project, the proposed structure is glulam timber columns, beams and panels. The typical 32' x 32' spatial module typical for modern hospitals can be used with CLT construction and reasonable floor deck depths if an intermediate beam is used between the column bays, similar to the Clay Creative project indicated in Figure 148, which has 30'x30' column bay with intermediate beams to allow deck spans not to exceed 15 feet. Proposed for this project is a 32' x 32' gride with intermediate beams at the 16 (half-bay) line. At the base of the structure is a concrete "bathtub" foundation to retain the slope on the north, west and east sides of the project.

The 2021 International Building Code (IBC) will allow I-2 occupancies (which typically apply to hospitals) to have fire protected heavy timber construction up to 7 stories above grade plane. Research indicates engineered wood structures typically have lower embodied energy as well as carbon sequestration, which is related to cleaner air for human health. However, the required fire protection for any I-2 structure, whether wood, steel, or concrete affects the ability of the building to make its structure directly

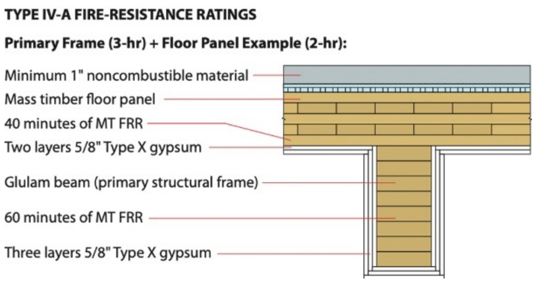


Figure 150: Fire Rated Mass Timber Assembly

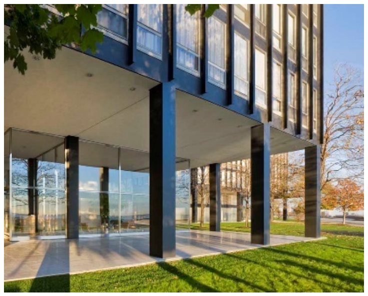


Figure 151: 880 Lakeshore Tower

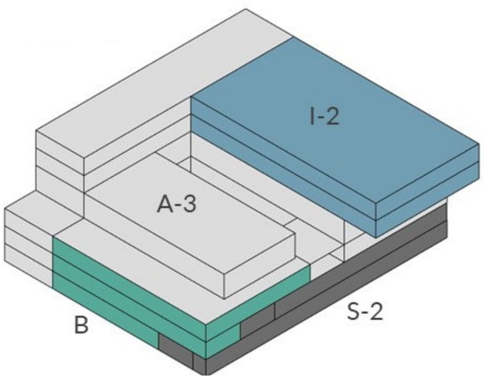


Figure 152: Separated Occupancy Diagram

visible. The 2021 IBC prescribes a noncombustible covering of gypsum board or equivalent, which would conceal the wood structure. Mies van der Rohe faced a similar challenge at 880 Lakeshore Tower, but in the interest of material authenticity, covered the rated steel columns with another layer of finished steel to help convey the message that the building structure is steel (Figure 151).

For this project, the different functional areas of the building were divided into multiple occupancies separated with fire barriers (rating as directed by IBC) so that non-institutional areas of the building could have the wood structure exposed at the interior for both authenticity, stress reduction through connection to biophilic patterns and multisensory stimulation. At areas of I-2 occupancy, wood structure can be expressed only through the use of applied wood finishes over the fire rated assemblies. Concrete column base assemblies would also be used at the parking areas (S-2).

Figure 153: Geothermal Well Diagram

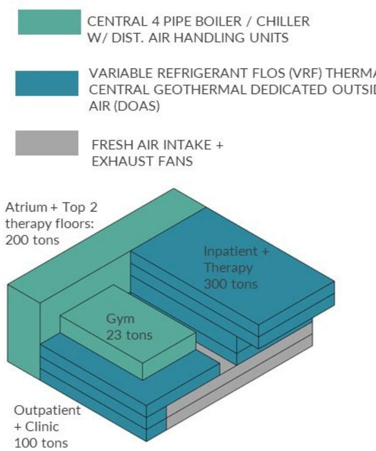


Figure 154: HVAC System Types

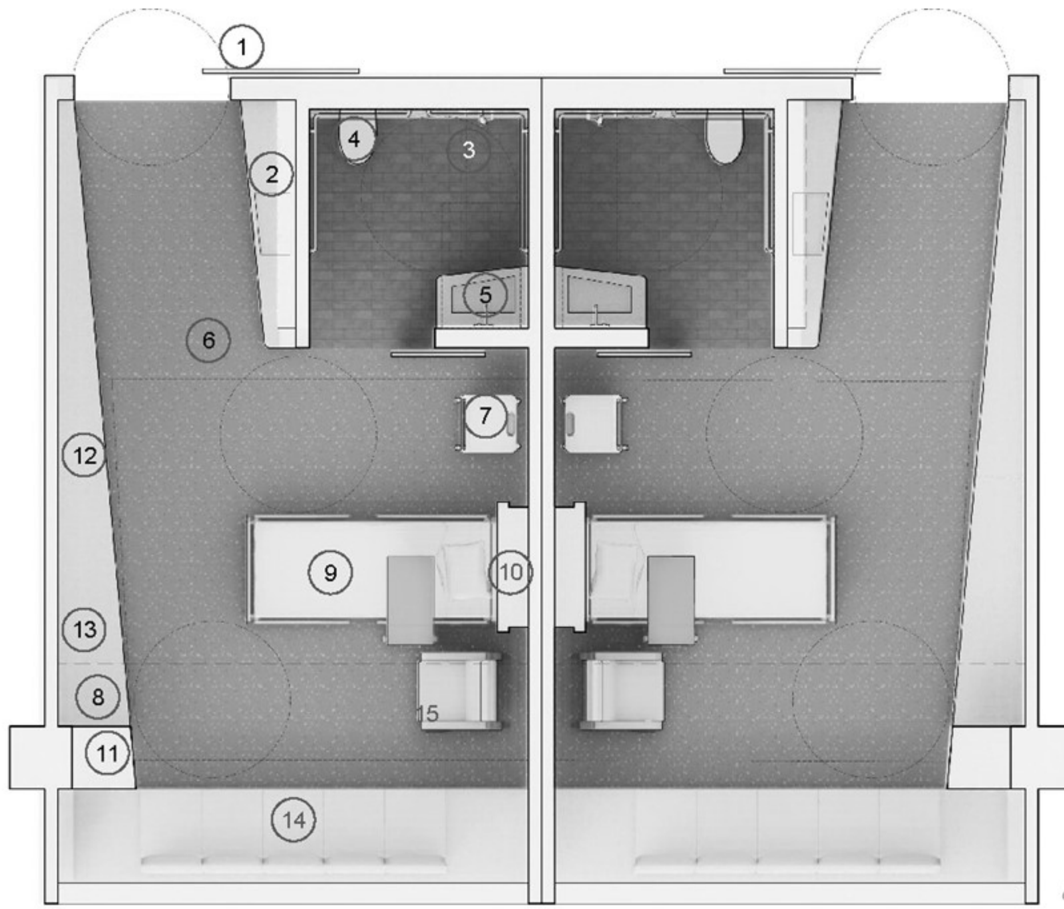
Systems. Analysis of the site indicates that if placed under the ground floor, geothermal well capacity is estimated to be about 140 tons (42 wells at 32' on center at 500' depth), not enough to cover the estimated HVAC load of the entire building. Therefore, a variety of HVAC systems were proposed for different areas of the project. The inpatient wing, consisting of smaller patient room and therapy spaces, is proposed to have energy efficient Variable Refrigerant Flow system for sensible heat and cooling, plus a Central Geothermal Dedicated Outside Air System (DOAS) to provide fresh air to these spaces. Smaller ductwork associated with a DOAS and VRF systems also mitigates the need for greater floor-to-floor heights. The larger atrium space and therapy gym will be supported by a central 4 pipe boiler/chiller system with distributed air handling units.

Figure 155: View from Patient Room Entry

Inpatient Department. The inpatient department is laid out with inpatient rooms along the perimeter, with support services in the core. To provide more spatial openness and hierarchy, the nurse stations are designed as open zones serving a subset of 10 rooms each. Special family rooms are located at the corners of the wing to provide a variety of scales of space and experience for patients who might be initially limited to a single floor due to mobility limitations. The large family kitchen / living areas have outdoor patios to reinforce multisensory potential, as well as provide functional therapy opportunities for cooking and regular household activities. Private patient rooms have private baths on the corridor side of the living space to provide some intermediate zoning of space from the corridor for enhanced privacy as well as for staff needs. The staff side of the vestibule allows staff to face patients while washing hands and changing personal protective equipment. This space also has a full height mirror with mid-height counter rail that allows enhanced visibility of the bed area from the corridor as well as a space for in-room therapy.

Figure 156: Level 5+6 Floor Plans

1. 5 foot opening
2. Staff Wash-Prep
3. Shower
4. Water Closet
5. Lavatory
6. 42” sliding bath entry
7. Staff Cart & Storage
8. Under Counter Refrigerator
9. Patient Bed
10. Headwall Zone (16” deep)
11. Wardrobe
12. Patient Storage / Display Counter
13. TV/Monitor
14. Seating / Sleeping Furniture
15. Guest Chair
16. LED Light Panel
17. Acoustical Ceiling
18. Operable Windows



PATIENT ROOM

Figure 157: Patient Room Plan

Within the patient room the design of the footwall is intended to mitigate cognitive disability through a modulated open storage system that allows patients to populate the portion of the room most visible from the bed with personal belongings and images. (Figure 158 and Figure 159). The use of wood on vertical surfaces is intended to place it in areas less prone to wear and tear to encourage the use of natural wood products for authenticity. The exterior wall zone is designed with movable furniture to support flexible use by family members for sitting, working, or sleeping (Figure 160). Exterior windows are designed with zones of panes for view versus operable function. These approaches allow more control over the patient room experience to accommodate a variety of patient sensitivities and preferences. Overall, the application of design guidelines for an ecological approach to rehabilitation affect all scales of design, including site and facility planning, exterior and interior experience, and detailed elements.

Figure 158: Patient Room View from Bed to Footwall

Figure 159: Patient Room View from Family Zone

Figure 160: Patient Room View from Bed to Exterior

9 CONCLUSION

To better respond the human experience of the built environment through the embodied brain, ecological psychology provides a guidepost for the development of design guidelines. In the area of TBI rehabilitation, neurodiversity and variety of ability of patients pushes the envelope of potential areas of constraint and opportunity for the design of the built environment. As embraced by the World Health Organization, a complete approach to activity requires consideration of context, both physical and social. Ecological approaches to rehabilitation address not just pathological aspects of TBI, but also impact the development of functional ability and quality of life. Design guidelines point to affordances which direct activity of multiple users to provide the externally supportive measures needed by TBI patients, family, and staff Through design for community interaction, encouraging movement, therapy throughout the facility, authenticity, respite, and multisensory stimulation design of the built environment can be more ecologically supportive of not just TBI patients, but a neurodiverse population in the greater built environment.

The unique impact of the ecological design guidelines to address issues of human health and well-being is that the built environment not only meets functional space needs but also invites and affords synergistic activities and behaviors of a variety of people at multiple scales. At the next level of architectural development, more opportunities for ecological synergies should emerge as the life cycle analysis of various systems are analyzed at a greater level of detail. This approach challenges architects and designers to have a heightened awareness of multisensory aspects of experience which are often difficult to represent and/or simulate in early design studies. By challenging impoverished representational notions of perception and prioritizing the embodied experience, the design of the built environment becomes more complex, but also more strategically impactful.

NOTES

[1] Eryn Brown, "Digging into Our Consciousness," accessed April 11, 2021, https://medicalxpress.com/news/2011-05-consciousness.html.
[2] Antonio R. Damasio, *Descartes' Error: Emotion, Reason, and the Human Brain* (New York, NY: Penguin Books, 2005).
[3] Baoqi Dang et al., "Rehabilitation Treatment and Progress of Traumatic Brain Injury Dysfunction," *Neural Plasticity* 2017 (2017), https://doi.org/10.1155/2017/1582182.
[4] National Institute of Neurological Disorders and Stroke and National Institutes of Health, "Traumatic Brain Injury: Hope through Research," February 2020, https://www.ninds.nih.gov/sites/default/files/traumatic_brain_injury_htr_february_2020_508c_1.pdf.
[5] "What Happens When You Get a Brain Injury in Different Areas of Your Brain?," SmartAdvocate® - The best plaintiff personal injury case management software, accessed December 11, 2020, https://www.smartadvocate.com/News/Blog/what-happens-when-you-get-a-brain-injury.
[6] National Institute of Neurological Disorders and Stroke and National Institutes of Health, "Traumatic Brain Injury: Hope through Research."
[7] CARF, "Medical Program Descriptions," 2020.
[8] Jeffrey P. Cuthbert et al., "Unemployment in the United States After Traumatic Brain Injury for Working-Age Individuals: Prevalence and Associated Factors 2 Years Postinjury," *The Journal of Head Trauma Rehabilitation* 30, no. 3 (2015): 160–74, https://doi.org/10.1097/HTR.0000000000000090.
[9] Raj G. Kumar et al., "Lifetime History of Traumatic Brain Injury Is Associated with Increased Loneliness in Adults: A US Nationally Representative Study," *International Journal of Geriatric Psychiatry* 35, no. 5 (2020): 553–63, https://doi.org/10.1002/gps.5271.
[10] Daniela Virgínia Vaz et al., "Towards an Ecologically Grounded Functional Practice in Rehabilitation," *Human Movement Science* 52 (April 1, 2017): 117–32, https://doi.org/10.1016/j.humov.2017.01.010.
[11] Brenna Costello, "Advancing Rehabilitation: Design That Considers Physical and Cognitive Disabilities," in *Architecture and Health: Guiding Principles for Practice*, ed. Dina Battisto and Jacob Wilhel (Routledge, 2020), Ch. 4.
[12] Zsolt Palatinus and Claire Michaels, "A Ten Commandments for Ecological Psychology," 2014, https://doi.org/10.4324/9781315775845.ch2.
[13] Vaz et al., "Towards an Ecologically Grounded Functional Practice in Rehabilitation."
[14] World Health Organization, "Towards a Common Language for Functioning, Disability and Health: ICF," 2002.
[15] Palatinus and Michaels, "A Ten Commandments for Ecological Psychology."
[16] Stuart Cowan and Sim Van der Ryn, *Ecological Design, Tenth Anniversary Edition* (Washington, UNITED STATES: Island Press, 2007), http://ebookcentral.proquest.com/lib/clemson/detail.action?docID=3317637.

[17] Michael D. Franzen and Karen L. Wilhelm, “Conceptual Foundations of Ecological Validity in Neuropsychological Assessment,” in *Ecological Validity of Neuropsychological Testing* (Delray Beach, FL, England: Gr Press/St Lucie Press, Inc, 1996), 91–112.
[18] Centers for Disease Control and Prevention (CDC), “Report to Congress on Traumatic Brain Injury Epidemiology and Rehabilitation,” January 31, 2019, https://www.cdc.gov/traumaticbraininjury/pubs/congress_epi_rehab.html.
[19] Centers for Disease Control and Prevention (CDC).
[20] CDC Injury Center, “TBI: Get the Facts,” accessed February 7, 2020, https://www.cdc.gov/traumaticbraininjury/get_the_facts.html.
[21] CDC Injury Center.
[22] CDC Injury Center.
[23] CDC Injury Center.
[24] CDC Injury Center.
[25] CDC Injury Center.
[26] Centers for Disease Control and Prevention (CDC), “Report to Congress on Traumatic Brain Injury Epidemiology and Rehabilitation.”
[27] Cuthbert et al., “Unemployment in the United States After Traumatic Brain Injury for Working-Age Individuals.”
[28] Centers for Disease Control and Prevention (CDC), “Report to Congress on Traumatic Brain Injury Epidemiology and Rehabilitation.”
[29] Centers for Disease Control and Prevention (CDC).
[30] Centers for Disease Control and Prevention (CDC).
[31] “The Glasgow Structured Approach to Assessment of the Glasgow Coma Scale,” accessed December 9, 2020, https://www.glasgowcomascale.org/.
[32] Philippe Azouvi, “Rehabilitation of Cognitive Deficits After Traumatic Brain Injury,” in *Traumatic Brain Injury*, ed. Claire Vallat-Azouvi, Ramon Diaz-Arrastia, and Pieter Vos (Hoboken, UNITED KINGDOM: John Wiley & Sons, Incorporated, 2015), 165–79, http://ebookcentral.proquest.com/lib/clemson/detail.action?docID=1901845.
[33] National Institute of Neurological Disorders and Stroke and National Institutes of Health, “Traumatic Brain Injury: Hope through Research.”
[34] Mayo Clinic, “Traumatic Brain Injury - Symptoms and Causes,” Mayo Clinic, accessed December 10, 2020, https://www.mayoclinic.org/diseases-conditions/traumatic-brain-injury/symptoms-causes/syc-20378557.
[35] Mayo Clinic.
[36] Mayo Clinic.
[37] Mayo Clinic.
[38] Mayo Clinic.
[39] Mayo Clinic.
[40] Costello, “Advancing Rehabilitation: Design That Considers Physical and Cognitive Disabilities.”
[41] Eunjeong Ko and Eun Yi Kim, “A Vision-Based Wayfinding System for Visually Impaired People Using Situation Awareness and Activity-Based Instructions,” *Sensors (Basel, Switzerland)* 17, no. 8 (August 16, 2017), https://doi.org/10.3390/s17081882.
[42] David X. Marquez et al., “Older Adult Strategies for Community Wayfinding,” *Journal of Applied Gerontology* 36, no. 2 (February 1, 2017): 213–33, https://doi.org/10.1177/0733464815581481.
[43] Costello, “Advancing Rehabilitation: Design That Considers Physical and Cognitive Disabilities.”
[44] Costello.

[45] Centers for Disease Control and Prevention (CDC), "Report to Congress on Traumatic Brain Injury Epidemiology and Rehabilitation."
[46] Centers for Disease Control and Prevention (CDC).
[47] Centers for Disease Control and Prevention (CDC).
[48] Centers for Disease Control and Prevention (CDC).
[49] Kelly Darmofal, *Lost in My Mind: Recovering from TBI*, 2019.
[50] Darmofal.
[51] Darmofal.
[52] Darmofal.
[53] "The Glasgow Structured Approach to Assessment of the Glasgow Coma Scale."
[54] Trisha Meili, *I Am the Central Park Jogger: A Story of Hope and Possibility* (Scribner, 2004).
[55] Lee Woodruff and Bob Woodruff, *In an Instant: A Family's Journey of Love and Healing* (Random House Trade Paperbacks, 2008).
[56] Woodruff and Woodruff.
[57] "Bob Woodruff and Wife Pen Recovery Memoir," NPR.org, accessed April 14, 2021, https://www.npr.org/templates/story/story.php?storyId=7618702.
[58] Woodruff and Woodruff, *In an Instant: A Family's Journey of Love and Healing*.
[59] Woodruff and Woodruff.
[60] Woodruff and Woodruff.
[61] Woodruff and Woodruff.
[62] Woodruff and Woodruff.
[63] Woodruff and Woodruff.
[64] Woodruff and Woodruff.
[65] Woodruff and Woodruff.
[66] Woodruff and Woodruff.
[67] Woodruff and Woodruff.
[68] Woodruff and Woodruff.
[69] Jill Bolte Taylor, *My Stroke of Insight: A Brain Scientist's Personal Journey* (New York: Penguin, 2006).
[70] Costello, "Advancing Rehabilitation: Design That Considers Physical and Cognitive Disabilities."
[71] Sean M. Phelan et al., "Perceived Stigma, Strain, and Mental Health among Caregivers of Veterans with Traumatic Brain Injury," *Disability and Health Journal* 4, no. 3 (July 2011): 177–84, https://doi.org/10.1016/j.dhjo.2011.03.003.
[72] Sook-Kyung C. Kwon et al., "Stress and Traumatic Brain Injury: A Behavioral, Proteomics, and Histological Study," *Frontiers in Neurology* 2 (March 7, 2011), https://doi.org/10.3389/fneur.2011.00012.
[73] Ann N. Hoffman et al., "Sensory Sensitivity as a Link between Concussive Traumatic Brain Injury and PTSD," *Scientific Reports* 9, no. 1 (September 25, 2019): 13841, https://doi.org/10.1038/s41598-019-50312-y.
[74] Elena Fiabane et al., "Occupational Stress and Job Satisfaction of Healthcare Staff in Rehabilitation Units," n.d., 11.
[75] Kumar et al., "Lifetime History of Traumatic Brain Injury Is Associated with Increased Loneliness in Adults."
[76] Stephen D. Gill, Toni Hogg, and Pamela J. Dolley, "Loneliness during Inpatient Rehabilitation: Results of a Qualitative Study," *International Journal of Rehabilitation Research* 39, no. 1 (March 2016): 84–86, https://doi.org/10.1097/MRR.0000000000000139.
[77] Institute of Medicine, *Cognitive Rehabilitation Therapy for Traumatic Brain Injury: Evaluating the Evidence* (Washington, DC: The National Academies Press, 2011), https://doi.org/10.17226/13220.

[78] Kumar et al., "Lifetime History of Traumatic Brain Injury Is Associated with Increased Loneliness in Adults."
[79] Centers for Disease Control and Prevention (CDC), "Report to Congress on Traumatic Brain Injury Epidemiology and Rehabilitation."
[80] Corwin Boake and Leonard Diller, "History of Rehabilitation for Traumatic Brain Injury," in *Rehabilitation for Traumatic Brain Injury*, ed. Walter M. High et al. (Oxford, UNITED STATES: Oxford University Press, Incorporated, 2005), http://ebookcentral.proquest.com/lib/clemson/detail.action?docID=4703304.
[81] Marguerite Hays, "A Historical Look at the Establishment of the Department of Veterans Affairs Research and Development Program" (VA Office of Research and Development), accessed April 21, 2021, https://www.research.va.gov/pubs/ord-history.cfm.
[82] Department of Veterans Affairs, "History - VA History - About VA," General Information, accessed March 16, 2021, https://www.va.gov/about_va/vahistory.asp.
[83] "Patient Ward at Veterans Administration Hospital, October 1953 | Ann Arbor District Library," accessed April 21, 2021, https://aadl.org/node/314370.
[84] Boake and Diller, "History of Rehabilitation for Traumatic Brain Injury."
[85] David X. Cifu et al., "The History and Evolution of Traumatic Brain Injury Rehabilitation in Military Service Members and Veterans," *American Journal of Physical Medicine & Rehabilitation* 89, no. 8 (August 2010): 688–94, https://doi.org/10.1097/PHM.0b013e3181e722ad.
[86] Cifu et al.
[87] Boake and Diller, "History of Rehabilitation for Traumatic Brain Injury."
[88] Clay Risen, "Yehuda Ben-Yishay, Pioneer in Treating Brain Injuries, Dies at 88," *The New York Times*, April 9, 2021, sec. Health, https://www.nytimes.com/2021/04/09/health/yehuda-ben-yishay-dead.html.
[89] CARF, "History," accessed December 12, 2020, http://www.carf.org/About/History/.
[90] Boake and Diller, "History of Rehabilitation for Traumatic Brain Injury."
[91] Boake and Diller.
[92] Boake and Diller.
[93] Centers for Disease Control and Prevention (CDC), "Report to Congress on Traumatic Brain Injury Epidemiology and Rehabilitation."
[94] Centers for Disease Control and Prevention (CDC).
[95] Centers for Disease Control and Prevention (CDC).
[96] Joseph Giacina, Andrea Christoforou, and Michael Bergin, "Rehabilitation Access and Outcome after Severe Traumatic Brain Injury Briefing Book" (Rehabilitation Access and Outcome After Severe Traumatic Brain Injury: A TBI Model System-Sponsored Stakeholder Summit, Washington, DC, 2016).
[97] Centers for Disease Control and Prevention (CDC), "Report to Congress on Traumatic Brain Injury Epidemiology and Rehabilitation."
[98] Giacina, Christoforou, and Bergin, "Rehabilitation Access and Outcome after Severe Traumatic Brain Injury Briefing Book."
[99] CARF, "Medical Program Descriptions."
[100] Centers for Disease Control and Prevention (CDC), "Report to Congress on Traumatic Brain Injury Epidemiology and Rehabilitation."
[101] "Traumatic Brain Injury - TBI Multidisciplinary Healthcare Team," accessed April 14, 2021, https://tbi.cemmlibrary.org/Moderate-to-Severe-TBI/TBI-Multidisciplinary-Healthcare-Team.
[102] "Traumatic Brain Injury - TBI Multidisciplinary Healthcare Team."

[103] "Traumatic Brain Injury - TBI Multidisciplinary Healthcare Team."
[104] "Traumatic Brain Injury - TBI Multidisciplinary Healthcare Team."
[105] "Traumatic Brain Injury - TBI Multidisciplinary Healthcare Team."
[106] "Traumatic Brain Injury - TBI Multidisciplinary Healthcare Team."
[107] "Traumatic Brain Injury - TBI Multidisciplinary Healthcare Team."
[108] "Traumatic Brain Injury - TBI Multidisciplinary Healthcare Team."
[109] "Traumatic Brain Injury - TBI Multidisciplinary Healthcare Team."
[110] "Traumatic Brain Injury - TBI Multidisciplinary Healthcare Team."
[111] "Traumatic Brain Injury - TBI Multidisciplinary Healthcare Team."
[112] Centers for Disease Control and Prevention (CDC), "Report to Congress on Traumatic Brain Injury Epidemiology and Rehabilitation."
[113] Institute of Medicine, *Cognitive Rehabilitation Therapy for Traumatic Brain Injury: Evaluating the Evidence*.
[114] Alex Wilson, "How to Make a Hospital Resilient: A Tour of Spaulding Rehab," *Resilient Design Institute* (blog), February 3, 2015, https://www.resilientdesign.org/how-to-make-a-hospital-resilient-a-tour-of-spaulding-rehabilitation-center/.
[115] "AbilityLab Home," Shirley Ryan AbilityLab, accessed December 10, 2020, https://www.sralab.org/home.
[116] "Rancho Los Amigos National Rehabilitation Center," SmithGroup, accessed December 10, 2020, https://www.smithgroup.com/projects/rancho-los-amigos-national-rehabilitation-center.
[117] Craig Hospital 3425 S. Clarkson St Englewood and CO 80113 U. S. A. Main Line 303-789-8000 Nurse Advice Line 1-800-247-0257, "Craig Hospital," Craig Hospital, accessed December 10, 2020, https://craighospital.org/.
[118] Costello, "Advancing Rehabilitation: Design That Considers Physical and Cognitive Disabilities."
[119] "The NICoE: Ten Years of Healing 'The Invisible Wounds of War,'" Military Health System, June 30, 2020, http://health.mil/News/Articles/2020/06/30/The-NICoE-Ten-year-of-Healing-The-Invisible-Wounds-of-War.
[120] Hoffman et al., "Sensory Sensitivity as a Link between Concussive Traumatic Brain Injury and PTSD."
[121] Vaz et al., "Towards an Ecologically Grounded Functional Practice in Rehabilitation."
[122] Vaz et al.
[123] Vaz et al.
[124] "Definition of ECOLOGY," accessed March 16, 2021, https://www.merriam-webster.com/dictionary/ecology.
[125] Vaz et al., "Towards an Ecologically Grounded Functional Practice in Rehabilitation."
[126] Claire Michaels and Claudia Carello, *Direct Perception* (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1981).
[127] Vaz et al., "Towards an Ecologically Grounded Functional Practice in Rehabilitation."
[128] M Turvey, "Perception: The Ecological Approach," in *Encyclopedia of Cognitive Science*, ed. L Nadel (Nature Publishing Group, 2003), 538–41.
[129] Michaels and Carello, *Direct Perception*.
[130] Palatinus and Michaels, "A Ten Commandments for Ecological Psychology."
[131] Mace and Heft, "Ecological Approach," 2 vols., Encyclopedia of Perception (Sage Publications, 2010), 375–80.
[132] Turvey, "Perception: The Ecological Approach."
[133] Turvey.
[134] Palatinus and Michaels, "A Ten Commandments for Ecological Psychology."
[135] Michaels and Carello, *Direct Perception*.
[136] Michaels and Carello.
[137] Cowan and Van der Ryn, *Ecological Design, Tenth Anniversary Edition*.
[138] Franzen and Wilhelm, "Conceptual Foundations of Ecological Validity in Neuropsychological Assessment."

[139] Vaz et al., "Towards an Ecologically Grounded Functional Practice in Rehabilitation."
[140] Lynn G. Irwin and Dónal G. Fortune, "Schools-Based Interventions for Reducing Stigmatization of Acquired Brain Injury: The Role of Interpersonal Contact and Visible Impairment," *Archives of Clinical Neuropsychology* 29, no. 2 (March 1, 2014): 194–205, https://doi.org/10.1093/arclin/act118.
[141] Irwin and Fortune.

[142] Scott C. Brown et al., "The Relationship of Built Environment to Perceived Social Support and Psychological Distress in Hispanic Elders: The Role of 'Eyes on the Street,'" *The Journals of Gerontology: Series B* 64B, no. 2 (March 1, 2009): 234–46, https://doi.org/10.1093/geronb/gbn011.
[143] R.S. Ulrich, "A Theory of Supportive Design for Healthcare Facilities," *Journal of Health Care Design* 9 (n.d.): 3–7.
[144] Jon Roeckelein, ed., "Rotter's Social Learning Theory," in *Elsevier's Dictionary of Psychological Theories* (Elsevier Science & Technology, 2006), http://libproxy.clemson.edu/login?url=https://search.credoreference.com/content/entry/estpsyctheory/rotter_s_social_learning_theory/0?institutionId=1831.
[145] "Healing the Hospital," *Contract Design* (blog), accessed April 14, 2021, https://contractdesign.com/galleries/projects-healthcare/healing-the-hospital/.
[146] Abigail Gillespie, "Spaulding Rehabilitation Hospital – Perkins&Will," accessed April 15, 2021, https://perkinswill.com/project/spaulding-rehabilitation-hospital/.
[147] Wilson, "How to Make a Hospital Resilient."
[148] Grace S. Griesbach, "Exercise After Traumatic Brain Injury: Is It a Double-Edged Sword?," *PM&R* 3, no. 6S (2011): S64–72, https://doi.org/10.1016/j.pmrj.2011.02.008.
[149] Ko and Kim, "A Vision-Based Wayfinding System for Visually Impaired People Using Situation Awareness and Activity-Based Instructions."
[150] Azouvi, "Rehabilitation of Cognitive Deficits After Traumatic Brain Injury."
[151] Dak Kopek, *Environmental Psychology for Design*, Third (New York, NY: Fairchild Books, 2018).
[152] Kevin Lynch, *The Image of the City* (MIT Press, 1960).
[153] Marquez et al., "Older Adult Strategies for Community Wayfinding."
[154] Steffen Werner and Laura E. Schindler, "The Role of Spatial Reference Frames in Architecture: Misalignment Impairs Way-Finding Performance," *Environment and Behavior* 36, no. 4 (July 1, 2004): 461–82, https://doi.org/10.1177/0013916503254829.
[155] Edie Cohen, "Three Major Firms Collaborate on Massive Shirley Ryan AbilityLab in Chicago," Interior Design, July 7, 2017, https://www.interiordesign.net/projects/13417-three-major-firms-collaborate-on-massive-shirley-ryan-abilitylab-in-chicago/.
[156] "Design + Structure," Shirley Ryan AbilityLab, accessed April 16, 2021, https://www.sralab.org/experience/design-structure.
[157] "Herzog & de Meuron Completes Extension of REHAB Clinic in Basel," World Architecture Community, accessed April 16, 2021, https://worldarchitecture.org/article-links/ecnnf/herzog-de-meuron-completes-extension-of-rehab-clinic-in-basel.html.
[158] Vaz et al., "Towards an Ecologically Grounded Functional Practice in Rehabilitation."

[159] Kopek, *Environmental Psychology for Design*.
[160] Kopek.
[161] Albert Bandera, *Social Foundations of Thought and Action : A Social Cognitive Theory* (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1986).
[162] Amy Haddad, Regina Doherty, and Ruth Purtilo, "Chapter 10 - Respectful Communication in an Information Age," in *Health Professional and Patient Interaction (Ninth Edition)*, ed. Amy Haddad, Regina Doherty, and Ruth Purtilo (W.B. Saunders, 2019), 141–65, https://doi.org/10.1016/B978-0-323-53362-1.00010-4.
[163] Palatinus and Michaels, "A Ten Commandments for Ecological Psychology."
[164] Apurba Barman, Ahana Chatterjee, and Rohit Bhide, "Cognitive Impairment and Rehabilitation Strategies After Traumatic Brain Injury," *Indian Journal of Psychological Medicine* 38, no. 3 (2016): 172–81, https://doi.org/10.4103/0253-7176.183086.
[165] Rob Withagen and Claire Michaels, "The Role of Feedback Information for Calibration and Attunement in Perceiving Length by Dynamic Touch.," *Journal of Experimental Psychology. Human Perception and Performance* 31 (January 1, 2006): 1379–90, https://doi.org/10.1037/0096-1523.31.6.1379.
[166] Irvin Rock, *Perception* (New York: Scientific American Library, 1995).
[167] Patrick Meehan, *Truth Against the World: Frank Llyd Wright Speaks for an Organic Architecture* (The Preservation Press, 1987).
[168] Meehan.
[169] John Lobell, *Between Silence and Light: Spirit in the Architecture of Louis I. Kahn*, 2000th ed. (Boston: Shambhala, 1979).
[170] "Paimio Sanatorium Is an Impressive Site | Design Stories," Finnish Design Shop COM, accessed April 17, 2021, https://www.finnishdesignshop.com/design-stories/architecture/alvar-aalto-and-the-colors-of-the-paimio-sanatorium.
[171] "Paimio Sanatorium Is an Impressive Site | Design Stories."
[172] "Paimio Sanatorium Is an Impressive Site | Design Stories."
[173] Alvar Aalto Foundation, "Paimio Sanatorium Conservation Management Plan 2016," n.d., 495.
[174] Costello, "Advancing Rehabilitation: Design That Considers Physical and Cognitive Disabilities."
[175] Kopek, *Environmental Psychology for Design*.
[176] Kopek.
[177] Esther Sternberg, *Healing Spaces: The Science of Place and Well-Being*, *Bibliovault OAI Repository*, *the University of Chicago Press*, 2009, https://doi.org/10.2307/j.ctvjghtgs.
[178] Costello, "Advancing Rehabilitation: Design That Considers Physical and Cognitive Disabilities."
[179] Ulrich, "A Theory of Supportive Design for Healthcare Facilities."
[180] R. Stephen Walsh et al., "Affiliative and 'Self-as-Doer' Identities: Relationships between Social Identity, Social Support, and Emotional Status amongst Survivors of Acquired Brain Injury (ABI)," *Neuropsychological Rehabilitation* 25, no. 4 (July 4, 2015): 555–73, https://doi.org/10.1080/09602011.2014.993658.
[181] Meili, *I Am the Central Park Jogger: A Story of Hope and Possibility*.
[182] Kopek, *Environmental Psychology for Design*.
[183] Ulrich, "A Theory of Supportive Design for Healthcare Facilities."
[184] Kopek, *Environmental Psychology for Design*.
[185] Kopek.
[186] Wilson, "How to Make a Hospital Resilient."
[187] Wilson.

FIGURE CREDITS

Figure 1: Leading Causes of Traumatic Brain Injury in the U.S., 2013

Centers for Disease Control and Prevention (CDC), "Report to Congress on Traumatic Brain Injury Epidemiology and Rehabilitation," January 31, 2019, https://www.cdc.gov/traumaticbraininjury/pubs/congress_epi_rehab.html.

Figure 2: Criteria to Classify TBI Severity

Adapted from Centers for Disease Control and Prevention (CDC). "Report to Congress on Traumatic Brain Injury Epidemiology and Rehabilitation," January 31, 2019. https://www.cdc.gov/traumaticbraininjury/pubs/congress_epi_rehab.html

Figure 3: What Happens When You Get a Brain Injury in Different Areas?

SmartAdvocate®. "What Happens When You Get a Brain Injury in Different Areas of Your Brain?" Accessed December 11, 2020. https://www.smartadvocate.com/News/Blog/what-happens-when-you-get-a-brain-injury.

Figure 4: Art of Leon Foggit and Chris Miller, TBI Patient

"Life After Brain Injury: The Role of Art in Rehabilitation." Accessed April 14, 2021. https://www.baat.org/About-BAAT/Blog/124/Life-After-Brain-Injury-The-Role-of-Art-in-Rehabilitation.

Figure 5: Kelly Bouldin Darmofal

Jenny Drabble, "A Survivor Must Believe...," Winston-Salem Journal, accessed December 10, 2020, https://journalnow.com/a-survivor-must-believe/article_2cb3a335-1bd6-5f1b-8eb0-9a17005fd913.html.

Figure 6: Trisha Meili

"Trisha Meili | Speaker Exchange Agency," accessed December 10, 2020, https://speakerexchangeagency.com/portfolio/trisha-meili/.

Figure 7: Bob Woodruff

: A. B. C. News, "Bob Woodruff Official Biography," ABC News, accessed December 10, 2020, https://abcnews.go.com/WNT/bob-woodruff-official-biography/story?id=127761.

Figure 8: Bob and Children

NPR.org. "Bob Woodruff and Wife Pen Recovery Memoir." Accessed April 14, 2021. https://www.npr.org/templates/story/story.php?storyId=7618702.

Figure 9 New York Presbyterian Hospital Rehabilitation Patient Room https://rehabmed.weill.cornell.edu/inpatient-rehabilitation-unit

Figure 10: Jill Bolte Taylor

"Publicity Photos - Dr. Jill Bolte Taylor." Accessed December 11, 2020. http://drjilltaylor.com/photos.html. (photo credit: Kip May)

Figure 11: Post WWII VA Hospital Ward

"Patient Ward at Veterans Administration Hospital, October 1953 | Ann Arbor District Library." Accessed April 21, 2021. https://aadl.org/node/314370.

Figure 12 TBI System of Care

Adapted from Joseph Giacina, Andrea Christoforou, and Michael Bergin, "Rehabilitation Access and Outcome after Severe Traumatic Brain Injury Briefing Book" (Rehabilitation Access and Outcome After Severe Traumatic Brain Injury: A TBI Model System-Sponsored Stakeholder Summit, Washington, DC, 2016).

Figure 13 Outline of a Day in Comprehensive Inpatient Rehabilitation

Source: created by author based on information from "Brain Injury Rehabilitation." Craig Hospital. Accessed April 12, 2021. https://craighospital.org/programs/traumatic-brain-injury.

Figure 14: Occupational Therapy Session

Communications, Florida International University-Digital. “Occupational Therapy.” Accessed April 14, 2021. https://cnhs.fiu.edu/academics/occupational-therapy/.

Figure 15: Speech Language Pathologist Session

Day, Jo Ann. “Speech-Language Therapy | Johns Hopkins Physical Medicine and Rehabilitation.” Accessed April 14, 2021. https://www.hopkinsmedicine.org/physical_medicine_rehabilitation/services/rehab-therapy/speech_language_therapy.html.

Figure 16: Physical Therapy for TBI

Main Line Health. “Lokomat Therapy.” Accessed April 14, 2021. https://www.mainlinehealth.org/specialties/rehab/outpatient/lokomat-therapy.

Figure 18: Rancho Los Amigos NRC

https://www.smithgroup.com/news/2018/renovated-rancho-los-amigos-national-rehabilitation-center-celebrates-project-milestone

Figure 17: Spaulding Rehabilitation Center

Centers for Disease Control and Prevention (CDC), “Report to Congress on Traumatic Brain Injury Epidemiology and Rehabilitation,” January 31, 2019, https://www.cdc.gov/traumaticbraininjury/pubs/congress_epi_rehab.html.

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https://craighospital.org/blog/new-patient-rooms-increase-privacy-convenience

Figure 19: Craig Hospital Inpatient room

https://craighospital.org/blog/new-patient-rooms-increase-privacy-convenience

Figure 22 Patient Floor Nurse Station

“Rehabilitation at Bridgeport Hospital.” Accessed April 26, 2021.
https://www.ynhh.org/services/rehabilitation/inpatient.aspx?__cf_chl_jschl_tk__=265e
2edcec8124c7db9165aa0c78a034c178a152-1619470424-0-
AfDjjqAiWJPwdEkORiA0ZCebmSHu3BJqyGE_JLOlX23G4nAOoxZLi2Msijzz2XeCuO
A8-
ZTU6GGyRopjyh08Xe0vKYKRFV0Bu0I1yHIlbtq5_T2E_D4KP3lfhpNyuvxBL3qlNVlm
k1YBM8XI6QqPLfZM8VaR98-
svOTuY9KlAbg3xSgYvkjXXqzqEjCO9tPsEFtc204s3W7KOLuMOPVxa6K3iwn0Rf1nd
XsStwuxGvDlWZFU4EWCCzNaIUJ5i964SBRm2DF8ikJx_NZ6f9BiHsDrhG0t_PkS5xA
0XQGT_rsQ_tIoYrtF8LwdRfDUcU-IEw4avEFct0puNSp2O5O2nQCGMwIqS-
C1i6EU2HmAaAYhOmhgQ5jIYDfyK1L6Lr02k617m7kwC9milbf6yBt0JR6T2C7L7Ff1
T6U3eG2PaXy0MG8MkCUuRHQdmEnSVfCD2g.

Figure 21: Interior Patient Corridor

“Morningside Nursing and Rehabilitation Center - Pricing, Photos and Floor Plans in Bronx, NY | Seniorly.” Accessed April 14, 2021. https://www.seniorly.com/skilled-nursing-facility/new-york/bronx/morningside-at-home.

Figure 23: Physical therapy space

“Rehabilitation at Bridgeport Hospital.” Accessed April 14, 2021. https://www.ynhh.org/services/rehabilitation/inpatient.aspx?__cf_chl_jschl_tk__=536e94e1efa55167a74c6a92df8f4f7bceba1075-1618424821-0-AbWiAyuY_A6R6KzE6ys6yzwBHHmQBt2AwCUuBuYY9uorGbkpFBH9brgi_hCUzBFRJri539J338sxW_g-dLvQChTeLB-_s-g24Y3mDay2QUrVR6Qp36ntaGddqdnEBwoLqqdOzQCvu4VEiUHSCMbzFls-cqjScR5CUcP5RU9MMYtQjurVXFCGZhtzRzck26bJOqVlNQBeesdkqQr-CYvzpGJEYJarXaUid4UD7bDJ6H6wz99DoIvJOWdu09Lo0iqa3RPUIoOMA8Ez_LDyonIRD6ciDsevWGrKhoxdUDFBxGR5klokVPAoSTwtYj9uoukM4qOP-o06qni0w_Bh2YtNZ1YGGmNlCHwm4tOC2P3btC22kybjRr0j7Xsn7Fd6TKelw0x0AWBFrUZDXNup2-ZIU4HUJ7aIN0J4_XSDHinsPSUu.

Figure 24: Newer PT space at Craig Hospital

SmithGroup. “Craig Hospital Expansion and Modernization.” Accessed April 14, 2021. ://www.smithgroup.com/projects/craig-hospital-expansion-and-modernization.

Figure 25 Therapy space with mats

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SmithGroup. “Craig Hospital Expansion and Modernization.” Accessed April 14, 2021. https://www.smithgroup.com/projects/craig-hospital-expansion-and-modernization.

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Smith Group JJR, “NICoE Music Therapy Space” (digital image)

Figure 28: Computer Assisted Rehabilitation Environment (CAREN) at NICoE

Military Health System. “The NICoE: Ten Years of Healing ‘The Invisible Wounds of War,’” June 30, 2020. https://www.health.mil/News/Articles/2020/06/30/The-NICoE-Ten-year-of-Healing-The-Invisible-Wounds-of-War.

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SmithGroup. “Rancho Los Amigos National Rehabilitation Center.” Accessed April 15, 2021. https://www.smithgroup.com/projects/rancho-los-amigos-national-rehabilitation-center

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SmithGroup. “Rancho Los Amigos National Rehabilitation Center.” Accessed April 15, 2021. https://www.smithgroup.com/projects/rancho-los-amigos-national-rehabilitation-center.

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SmithGroup. “Rancho Los Amigos National Rehabilitation Center.” Accessed April 15, 2021. https://www.smithgroup.com/projects/rancho-los-amigos-national-rehabilitation-center.

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SmithGroup. “National Intrepid Center of Excellence (NICoE).” Accessed April 17, 2021. https://www.smithgroup.com/projects/national-intrepid-center-of-excellence-nicoe.

Figure 33: Dining in Entry Hall

Leaders in Pharmaceutical Business Intelligence (LPBI) Group. “Swiss Paraplegic Centre, Nottwil, Switzerland – A World-Class Clinic for Spinal Cord Injuries,” March 24, 2017. https://pharmaceuticalintelligence.com/2017/03/23/swiss-paraplegic-centre-nottwil-switzerland-a-world-class-clinic-for-spinal-cord-injuries/.

Figure 34: NICoE Seating Area

ArchDaily. “Gallery of AIA Selects Four Projects for National Healthcare Design Awards - 7.” Accessed April 17, 2021. https://www.archdaily.com/274743/aia-selects-four-projects-for-national-healthcare-design-awards/nicoe-6_mackenzie.

Figure 35: Hospital Loading Dock

Orleans, Infrogmation of New. Scene on Cleveland Avenue, New Orleans Central Business District. Truck Loading Dock at Back Side of Hospital. June 2009. Photo by Infrogmation. https://commons.wikimedia.org/wiki/File:ClevelandAvHospitalTrucksNOLA.JPG.

Figure 36: Shirley Ryan Ability Lab Ambulance Entry

Cohen, Edie. “Three Major Firms Collaborate on Massive Shirley Ryan AbilityLab in Chicago.” Interior Design, July 7, 2017. https://www.interiordesign.net/projects/13417-three-major-firms-collaborate-on-massive-shirley-ryan-abilitylab-in-chicago/.

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SmithGroup. “Rancho Los Amigos National Rehabilitation Center.” Accessed April 15, 2021. https://www.smithgroup.com/projects/rancho-los-amigos-national-rehabilitation-center.

Figure 38: WHO 1980 Model of Disability

Vaz, Daniela Virgínia, Paula Lanna Silva, Marisa Cotta Mancini, Claudia Carello, and Jeffrey Kinsella-Shaw. “Towards an Ecologically Grounded Functional Practice in Rehabilitation.” Human Movement Science 52 (April 1, 2017): 117–32. https://doi.org/10.1016/j.humov.2017.01.010.

Figure 39: WHO 2001 International Classification of Functioning, Disability and Health (CIF)

Vaz, Daniela Virgínia, Paula Lanna Silva, Marisa Cotta Mancini, Claudia Carello, and Jeffrey Kinsella-Shaw. “Towards an Ecologically Grounded Functional Practice in Rehabilitation.” Human Movement Science 52 (April 1, 2017): 117–32. https://doi.org/10.1016/j.humov.2017.01.010. Adapted from World Health Organization (WHO). International Classification of Functioning, Disability and Health (ICF). Geneva, 2001.

Items in bold are components of function. Items in italics are components of disability.

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Created by Author

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“Optical Flow.” In Wikipedia, April 12, 2021. https://en.wikipedia.org/w/index.php?title=Optical_flow&oldid=1017413562.

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"Art of Rancho – Rancho Los Amigos Foundation." Accessed April 14, 2021. http://ranchofoundation.org/art-of-rancho/.

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"Rancho Los Amigos Foundation - "Roll Around The Ranch" Health & Wellness Fair." Accessed April 14, 2021. http://ranchofoundation.org/o/strokefair.html.

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"Eyes on the Street." Accessed April 15, 2021. https://collectiveimpactlab.com/2005/06/30/eyes-on-the-street/.

Figure 45 Suburban Commuters in Separate Cars

Justin Sullivan/Getty Images, "At 60, America's Interstate Highway System Is Showing Signs Of Age." Accessed April 15, 2021. https://www.wbur.org/hereandnow/2016/06/29/interstate-highway-system-age.

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Hoskins, Lisa

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Hoskins, Lisa

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Contract Design. “Healing the Hospital.” Accessed April 14, 2021. https://contractdesign.com/galleries/projects-healthcare/healing-the-hospital/.

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Building Design + Construction. “Healing Garden Doubles as Therapy Trails.” Accessed April 27, 2021. https://www.bdcnetwork.com/healing-garden-doubles-therapy-trails.

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Contract Design. “Healing the Hospital.” Accessed April 14, 2021. https://contractdesign.com/galleries/projects-healthcare/healing-the-hospital/.

Figure 52: Spaulding Rehab Hospital Dining Plaza

Copley + Wolff Photograph. “Lightcraft.” Accessed April 14, 2021. https://www.lightcraftgroup.com/rust.

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Lightcraft. “Lightcraft.” Accessed April 14, 2021. https://www.lightcraftgroup.com/rust.

Figure 54: Thomas Menino Park

"Mayor Thomas M. Menino Park - Inclusive Playground." Accessed April 14, 2021. https://www.playlsi.com/en/commercial-playground-equipment/playgrounds/mayor-thomas-m-menino-park/.

Figure 55: Rancho Los Amigos National Rehabilitation Center

SmithGroup. "Renovated Rancho Los Amigos National Rehabilitation Center Celebrates Project Milestone in Los Angeles." Accessed April 15, 2021. https://www.smithgroup.com/news/2018/renovated-rancho-los-amigos-national-rehabilitation-center-celebrates-project-milestone.

Figure 56: Craig Hospital Entry

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Hoskins, Lisa as adapted from Lynch, Kevin. The Image of the City. MIT Press, 1960.

Figure 58: Shirley Ryan Ability Lab Entry

Architizer. "Shirley Ryan AbilityLab by Clive Wilkinson Architects, HDR, Gensler," July 3, 2018. https://architizer.com/projects/shirley-ryan-abilitylab/.

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Photography: Michael Moran/Otto. Cohen, Edie. "Three Major Firms Collaborate on Massive Shirley Ryan AbilityLab in Chicago." Interior Design, July 7, 2017.

https://www.interiordesign.net/projects/13417-three-major-firms-collaborate-on-massive-shirley-ryan-abilitylab-in-chicago/.

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Shirley Ryan AbilityLab. “Design + Structure.” Accessed April 16, 2021. https://www.sralab.org/experience/design-structure.

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David Allison, “Basel Rehab Entry Courtyard” digital image

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World Architecture Community. “Herzog & de Meuron Completes Extension of REHAB Clinic in Basel.” Accessed April 16, 2021. https://worldarchitecture.org/article-links/ecnnf/herzog-de-meuron-completes-extension-of-rehab-clinic-in-basel.html.

Figure 63: Therapy Garden

“REHAB, Center for Spinal Cord and Brain Injuries by Herzog & de Meuron.” Accessed April 16, 2021. https://www.architecturalrecord.com/articles/13682-rehab-center-for-spinal-cord-and-brain-injuries-by-herzog-de-meuron.

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World Architecture Community. “Herzog & de Meuron Completes Extension of REHAB Clinic in Basel.” Accessed April 16, 2021. https://worldarchitecture.org/article-links/ecnnf/herzog-de-meuron-completes-extension-of-rehab-clinic-in-basel.html.

Figure 65: Basel Rehab Ground Floor Plan

Adapted from “DRAWINGS - HERZOG & DE MEURON.” Accessed April 15, 2021. https://www.herzogdemeuron.com/index/focus/940-focus-hospitals/drawings.html.

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David Allison, “Basel Rehab Courtyard” digital image

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David Allison, “Basel Rehab Garden” digital image

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Photo by Phil Skinner. Occupational Therapists Help Patients Improve Independence with Daily Living Activities. “Occupational Therapists Help Patients Improve Independence with Daily Living Activities.” Accessed April 16, 2021. http://bit.ly/1rGXcFX.

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Photo by Anton Grassl/Esto "Spaulding Rehabilitation Hospital | Boston." Accessed April 16, 2021. https://www.hfmmagazine.com/media/photos/7-spaulding-rehabilitation-hospital-boston.

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Gillespie, Abigail. "Spaulding Rehabilitation Hospital – Perkins&Will." Accessed April 16, 2021. https://perkinswill.com/project/spaulding-rehabilitation-hospital/.

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Herzog & de Meuron, 2002. 165 REHAB, Centre for Spinal Cord and Brain Injuries, Basel, Switzerland. [Online] Available at: http://www.herzogdemeuron.com/index/projects/complete-works/151-175/165-rehab-centre-for-spinal-cord-and-brain-injuries/IMAGE.html [Accessed: 29th October 2014].

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Pinterest. "(20) Pinterest." Accessed April 16, 2021. https://pin.it/72WBK4R

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Shirley Ryan AbilityLab. "Design + Structure." Accessed April 16, 2021. https://www.sralab.org/experience/design-structure.

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“Shirley Ryan AbilityLab | HDR.” Accessed April 16, 2021. /node/2518.

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timelessitaly. “Eye Trickery and Shattered Illusions in Rome.” Timeless Italy Travels (blog), November 1, 2013. https://timelessitalytravels.com/2013/11/01/eye-trickery-and-shattered-illusions-in-baroque-rome/.

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timelessitaly. “Eye Trickery and Shattered Illusions in Rome.” *Timeless Italy Travels* (blog), November 1, 2013. https://timelessitalytravels.com/2013/11/01/eye-trickery-and-shattered-illusions-in-baroque-rome/.

Figure 77: Kahn's Brick Parliament Design

...architecture of the earth and the living. “Louis Kahn – …architecture of the Earth and the Living.” Accessed April 17, 2021. https://warrenlawson.wordpress.com/tag/louis-kahn/.

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Photo by Fabrice Fouillet. ArchEyes. “Alvar Aalto’s Paimio Sanatorium / Hospital in Finland,” May 15, 2020. https://archeyes.com/paimio-sanatorium-alvar-aalto/.

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Photo by Gustaf Welin, Alvar Aalto Foundation. ArchEyes. "Alvar Aalto's Paimio Sanatorium / Hospital in Finland," May 15, 2020. https://archeyes.com/paimio-sanatorium-alvar-aalto/.

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ArchEyes. "Alvar Aalto's Paimio Sanatorium / Hospital in Finland," May 15, 2020. https://archeyes.com/paimio-sanatorium-alvar-aalto/.

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Finnish Design Shop COM. "Paimio Sanatorium Is an Impressive Site | Design Stories." Accessed April 17, 2021. https://www.finnishdesignshop.com/design-stories/architecture/alvar-aalto-and-the-colors-of-the-paimio-sanatorium.

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Finnish Design Shop COM. "Paimio Sanatorium Is an Impressive Site | Design Stories." Accessed April 17, 2021. https://www.finnishdesignshop.com/design-stories/architecture/alvar-aalto-and-the-colors-of-the-paimio-sanatorium.

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davis, andrea. “Lucile Packard Children’s Hospital Stanford – Perkins&Will.” Accessed April 17, 2021. https://perkinswill.com/project/lucile-packard-childrens-hospital-stanford/.

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davis, andrea. “Lucile Packard Children’s Hospital Stanford – Perkins&Will.” Accessed April 17, 2021. https://perkinswill.com/project/lucile-packard-childrens-hospital-stanford/.

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davis, andrea. “Lucile Packard Children’s Hospital Stanford – Perkins&Will.” Accessed April 17, 2021. https://perkinswill.com/project/lucile-packard-childrens-hospital-stanford/.

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davis, andrea. “Lucile Packard Children’s Hospital Stanford – Perkins&Will.” Accessed April 17, 2021. https://perkinswill.com/project/lucile-packard-childrens-hospital-stanford/.

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Hines, Mimi. “Women’s and Children’s Health – Perkins&Will.” Accessed April 14, 2021. https://perkinswill.com/area-of-expertise/womens-and-childrens-health/.

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Halkin Mason Photography. "HCD Mag." Accessed April 17, 2021. https://healthcaredesignmagazine.com/featured-firms-projects/musc-shawn-jenkins-childrens-hospital-and-pearl-tourville-womens-pavilion/.

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Halkin Mason Photography LLC. "HCD Mag." Accessed April 17, 2021. https://healthcaredesignmagazine.com/featured-firms-projects/musc-shawn-jenkins-childrens-hospital-and-pearl-tourville-womens-pavilion/.

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"Gallery of Spaulding Hospital / Perkins+Will - 1," ArchDaily, accessed December 10, 2020, https://www.archdaily.com/443408/spaulding-hospita-perkins-will/526d622be8e44ef4c2000583-spaulding-hospita-perkins-will-photo.

Figure 95: NICoE Central Park

ArchDaily. "Gallery of AIA Selects Four Projects for National Healthcare Design Awards - 7." Accessed April 17, 2021. https://www.archdaily.com/274743/aia-selects-four-projects-for-national-healthcare-design-awards/nicoe-6_mackenzie.

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SmithGroup. "National Intrepid Center of Excellence (NICoE)." Accessed April 17, 2021. https://www.smithgroup.com/projects/national-intrepid-center-of-excellence-nicoe.

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ArchDaily. "Gallery of AIA Selects Four Projects for National Healthcare Design Awards - 7." Accessed April 17, 2021. https://www.archdaily.com/274743/aia-selects-four-projects-for-national-healthcare-design-awards/nicoe-6_mackenzie.

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Hoskins, Lisa

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Gillespie, Abigail. "Spaulding Rehabilitation Hospital – Perkins&Will." Accessed April 15, 2021. https://perkinswill.com/project/spaulding-rehabilitation-hospital/.

Figure 102: Operable Windows

Wilson, Alex. "How to Make a Hospital Resilient: A Tour of Spaulding Rehab." Resilient Design Institute (blog), February 3, 2015. https://www.resilientdesign.org/how-to-make-a-hospital-resilient-a-tour-of-spaulding-rehabilitation-center/

Figure 103: Green Roofs and Gardens

Gillespie, Abigail. “Spaulding Rehabilitation Hospital – Perkins&Will.” Accessed April 17, 2021. https://perkinswill.com/project/spaulding-rehabilitation-hospital/.

Figure 104: Upper-Level Lobby at Roof Terrace

“HCD Mag.” Accessed April 17, 2021. https://healthcaredesignmagazine.com/trends/construction-engineering/winds-of-change/.

Figure 105: Corner Windows with Louvers

Figure 106: Pool

Anton Grass / Esto. ArchDaily. “Gallery of Spaulding Hospital / Perkins+Will - 2.” Accessed April 17, 2021. https://www.archdaily.com/443408/spaulding-hospita-perkins-will/526d66a6e8e44ef4c2000588-spaulding-hospita-perkins-will-photo.

Figure 107: Live Oak Bench

Wilson, Alex. “How to Make a Hospital Resilient: A Tour of Spaulding Rehab.” Resilient Design Institute (blog), February 3, 2015. https://www.resilientdesign.org/how-to-make-a-hospital-resilient-a-tour-of-spaulding-rehabilitation-center/.

Figure 108: Site Context

Figure 121: Level 2 Plan Diagram

Figure 122: Section AA Facing West

Figure 123: Level 3 Plan Diagram

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Figure 125: Level 4 Plan Diagram

Figure 127: Level 4 Plan Diagram

Figure 128: Northwest Entry

Figure 129: Levels 5+6 Plan Diagram

Figure 130: Section BB Facing West

Figure 131 Solar Green Roof

netconstructions.de, Michael Probst Stuckmann. “Green Roofs and Solar Energy | ZinCo Green Roof Systems.” ZinCo GmbH Nürtingen Germany. World. Accessed April 21, 2021. https://zinco-greenroof.com/systems/solar-energy.

Figure 133: Exterior from Southwest

Figure 132: Transparent Patterned Solar Panels

"BIPV En - SOLAXESS." Accessed April 21, 2021. https://www.solaxess.ch/informations-fr/bipv-fr/.

Figure 134: Transparent Patterned Solar Panels

"BIPV En - SOLAXESS." Accessed April 21, 2021. https://www.solaxess.ch/informations-fr/bipv-fr/.

Figure 135: Crab Orchard Stone Color + Coursing

"Flagstone." Accessed April 21, 2021. http://www.centurionstoneofthecarolinas.com/product/flagstone/.

Figure 136: South and West Facades (View from 19th Street and White Avenue)

Figure 137: Stepped Patio Areas Outside Along 19th Street

Figure 139: South Facade (White Avenue)

Figure 138: Cladding Example

ArchDaily. "Gallery of Thistle / 3DReid - 1." Accessed April 21, 2021. https://www.archdaily.com/791717/thistle-3dreid/578ec73fe58ece842c000074-thistle-3dreid-photo.

Figure 140: Therapy Gym Section

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Figure 143: Level 4 floor Plan (On grade with Clinch Avenue to North)

Figure 144: Level 4 Atrium Plan

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Figure 146: Section Axon of Atrium Facing West at Stair

Figure 147: Atrium View from North Entry

Hoskins, Lisa

Figure 148: Clay Creative Glulam Wood Beams

Mackenzie (digital image) Woodworks. "How Can I Create an Efficient Structural Grid for a Mass Timber Building?" *WoodWorks* (blog). Accessed April 21, 2021. https://www.woodworks.org/experttip/2019-efficient-structural-grid/.

Figure 149: Proposed Project Structure Diagram

Hoskins, Lisa

Figure 150: Fire Rated Mass Timber Assembly

"STRUCTURE Magazine | Tall Timber Buildings." Accessed April 21, 2021. https://www.structuremag.org/?p=16435.

Figure 151: 880 Lakeshore Tower

McManus, David. "860-880 Lake Shore Drive Chicago Building." e-architect, May 7, 2014. https://www.e-architect.com/chicago/lake-shore-drive-towers.

Figure 152: Separated Occupancy Diagram

Hoskins, Lisa

Figure 153: Geothermal Well Diagram

Figure 154: HVAC System Types

Figure 155: View from Patient Room Entry

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Figure 157: Patient Room Plan

Figure 158: Patient Room View from Bed to Footwall

Figure 159: Patient Room View from Family Zone

Figure 160: Patient Room View from Bed to Exterior

BIBLIOGRAPHY

Shirley Ryan AbilityLab. “AbilityLab Home.” Accessed December 10, 2020. https://www.sralab.org/home.

Azouvi, Philippe. “Rehabilitation of Cognitive Deficits After Traumatic Brain Injury.” In *Traumatic Brain Injury*, edited by Claire Vallat-Azouvi, Ramon Diaz-Arrastia, and Pieter Vos, 165–79. Hoboken, UNITED KINGDOM: John Wiley & Sons, Incorporated, 2015. http://ebookcentral.proquest.com/lib/clemson/detail.action?docID=1901845.

Bandera, Albert. *Social Foundations of Thought and Action : A Social Cognitive Theory*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1986.

Barman, Apurba, Ahana Chatterjee, and Rohit Bhide. “Cognitive Impairment and Rehabilitation Strategies After Traumatic Brain Injury.” *Indian Journal of Psychological Medicine* 38, no. 3 (2016): 172–81. https://doi.org/10.4103/0253-7176.183086.

Boake, Corwin, and Leonard Diller. “History of Rehabilitation for Traumatic Brain Injury.” In *Rehabilitation for Traumatic Brain Injury*, edited by Walter M. High, Angelle M. Sander, Margaret A. Struchen, Karen A. Hart, and Walter M. High. Oxford, UNITED STATES: Oxford University Press, Incorporated, 2005. http://ebookcentral.proquest.com/lib/clemson/detail.action?docID=4703304.

NPR.org. “Bob Woodruff and Wife Pen Recovery Memoir.” Accessed April 14, 2021. https://www.npr.org/templates/story/story.php?storyId=7618702.

Brown, Eryn. “Digging into Our Consciousness.” Accessed April 11, 2021. https://medicalxpress.com/news/2011-05-consciousness.html.

Brown, Scott C., Craig A. Mason, Joanna L. Lombard, Frank Martinez, Elizabeth Plater-Zyberk, Arnold R. Spokane, Frederick L. Newman, Hilda Pantin, and José Szapocznik. “The Relationship of Built Environment to Perceived Social Support and Psychological Distress in Hispanic Elders: The Role of ‘Eyes on the

Street.'" *The Journals of Gerontology: Series B* 64B, no. 2 (March 1, 2009): 234–46. https://doi.org/10.1093/geronb/gbn011.
CARF. "History." Accessed December 12, 2020. http://www.carf.org/About/History/.
———. "Medical Program Descriptions," 2020.
CDC Injury Center. "TBI: Get the Facts." Accessed February 7, 2020. https://www.cdc.gov/traumaticbraininjury/get_the_facts.html.
Centers for Disease Control and Prevention (CDC). "Report to Congress on Traumatic Brain Injury Epidemiology and Rehabilitation," January 31, 2019. https://www.cdc.gov/traumaticbraininjury/pubs/congress_epi_rehab.html.
Cifu, David X., Sara I. Cohen, Henry L. Lew, Michael Jaffee, and Barbara Sigford. "The History and Evolution of Traumatic Brain Injury Rehabilitation in Military Service Members and Veterans." *American Journal of Physical Medicine & Rehabilitation* 89, no. 8 (August 2010): 688–94. https://doi.org/10.1097/PHM.0b013e3181e722ad.
Cohen, Edie. "Three Major Firms Collaborate on Massive Shirley Ryan AbilityLab in Chicago." Interior Design, July 7, 2017. https://www.interiordesign.net/projects/13417-three-major-firms-collaborate-on-massive-shirley-ryan-abilitylab-in-chicago/.
Costello, Brenna. "Advancing Rehabilitation: Design That Considers Physical and Cognitive Disabilities." In *Architecture and Health: Guiding Principles for Practice*, edited by Dina Battisto and Jacob Wilhel, Ch. 4. Routledge, 2020.
Cowan, Stuart, and Sim Van der Ryn. *Ecological Design, Tenth Anniversary Edition*. Washington, UNITED STATES: Island Press, 2007. http://ebookcentral.proquest.com/lib/clemson/detail.action?docID=3317637.
Cuthbert, Jeffrey P., Cynthia Harrison-Felix, John D. Corrigan, Jeneita M. Bell, Juliet K. Haarbauer-Krupa, and A. Cate Miller. "Unemployment in the United States After Traumatic Brain Injury for Working-Age Individuals: Prevalence and Associated Factors 2 Years Postinjury." *The Journal of Head Trauma Rehabilitation* 30, no. 3 (2015): 160–74. https://doi.org/10.1097/HTR.0000000000000090.

Damasio, Antonio R. *Descartes' Error: Emotion, Reason, and the Human Brain*. New York, NY: Penguin Books, 2005.

Dang, Baoqi, Wenli Chen, Weichun He, and Gang Chen. "Rehabilitation Treatment and Progress of Traumatic Brain Injury Dysfunction." *Neural Plasticity* 2017 (2017). https://doi.org/10.1155/2017/1582182.

Darmofal, Kelly. *Lost in My Mind: Recovering from TBI*, 2019.

"Definition of ECOLOGY." Accessed March 16, 2021. https://www.merriam-webster.com/dictionary/ecology.

Department of Veterans Affairs. "History - VA History - About VA." General Information. Accessed March 16, 2021. https://www.va.gov/about_va/vahistory.asp.

Shirley Ryan AbilityLab. "Design + Structure." Accessed April 16, 2021. https://www.sralab.org/experience/design-structure.

Englewood, Craig Hospital 3425 S. Clarkson St, and CO 80113 U. S. A. Main Line 303-789-8000 Nurse Advice Line 1-800-247-0257. "Craig Hospital." Craig Hospital. Accessed December 10, 2020. https://craighospital.org/.

Fiabane, Elena, Ines Giorgi, D Musian, Cinzia Sguazzin, and P Argentero. "Occupational Stress and Job Satisfaction of Healthcare Staff in Rehabilitation Units," n.d., 11.

Foundation, Alvar Aalto. "Paimio Sanatorium Conservation Management Plan 2016," n.d., 495.

Franzen, Michael D., and Karen L. Wilhelm. "Conceptual Foundations of Ecological Validity in Neuropsychological Assessment." In *Ecological Validity of Neuropsychological Testing*, 91–112. Delray Beach, FL, England: Gr Press/St Lucie Press, Inc, 1996.

Giacina, Joseph, Andrea Christoforou, and Michael Bergin. "Rehabilitation Access and Outcome after Severe Traumatic Brain Injury Briefing Book." Washington, DC, 2016.

Gill, Stephen D., Toni Hogg, and Pamela J. Dolley. "Loneliness during Inpatient Rehabilitation: Results of a Qualitative Study." *International Journal of Rehabilitation Research* 39, no. 1 (March 2016): 84–86. https://doi.org/10.1097/MRR.0000000000000139.

Gillespie, Abigail. “Spaulding Rehabilitation Hospital – Perkins&Will.” Accessed April 15, 2021. https://perkinswill.com/project/spaulding-rehabilitation-hospital/.
Griesbach, Grace S. “Exercise After Traumatic Brain Injury: Is It a Double-Edged Sword?” *PM&R* 3, no. 6S (2011): S64–72. https://doi.org/10.1016/j.pmrj.2011.02.008.
Haddad, Amy, Regina Doherty, and Ruth Purtilo. “Chapter 10 - Respectful Communication in an Information Age.” In *Health Professional and Patient Interaction (Ninth Edition)*, edited by Amy Haddad, Regina Doherty, and Ruth Purtilo, 141–65. W.B. Saunders, 2019. https://doi.org/10.1016/B978-0-323-53362-1.00010-4.
Hays, Marguerite. “A Historical Look at the Establishment of the Department of Veterans Affairs Research and Development Program.” VA Office of Research and Development. Accessed April 21, 2021. https://www.research.va.gov/pubs/ord-history.cfm.
Contract Design. “Healing the Hospital.” Accessed April 14, 2021. https://contractdesign.com/galleries/projects-healthcare/healing-the-hospital/.
World Architecture Community. “Herzog & de Meuron Completes Extension of REHAB Clinic in Basel.” Accessed April 16, 2021. https://worldarchitecture.org/article-links/ecnnf/herzog-de-meuron-completes-extension-of-rehab-clinic-in-basel.html.
Hoffman, Ann N., Jamie Lam, David A. Hovda, Christopher C. Giza, and Michael S. Fanselow. “Sensory Sensitivity as a Link between Concussive Traumatic Brain Injury and PTSD.” *Scientific Reports* 9, no. 1 (September 25, 2019): 13841. https://doi.org/10.1038/s41598-019-50312-y.
Institute of Medicine. *Cognitive Rehabilitation Therapy for Traumatic Brain Injury: Evaluating the Evidence*. Washington, DC: The National Academies Press, 2011. https://doi.org/10.17226/13220.
Irwin, Lynn G., and Dónal G. Fortune. “Schools-Based Interventions for Reducing Stigmatization of Acquired Brain Injury: The Role of Interpersonal Contact and

Visible Impairment." *Archives of Clinical Neuropsychology* 29, no. 2 (March 1, 2014): 194–205. https://doi.org/10.1093/arclin/act118.
Ko, Eunjeong, and Eun Yi Kim. "A Vision-Based Wayfinding System for Visually Impaired People Using Situation Awareness and Activity-Based Instructions." *Sensors (Basel, Switzerland)* 17, no. 8 (August 16, 2017). https://doi.org/10.3390/s17081882.
Kopek, Dak. *Environmental Psychology for Design*. Third. New York, NY: Fairchild Books, 2018.
Kumar, Raj G., Katherine A. Ornstein, Evan Bollens-Lund, Eric M. Watson, Claire K. Ankuda, Amy S. Kelley, and Kristen Dams-O'Connor. "Lifetime History of Traumatic Brain Injury Is Associated with Increased Loneliness in Adults: A US Nationally Representative Study." *International Journal of Geriatric Psychiatry* 35, no. 5 (2020): 553–63. https://doi.org/10.1002/gps.5271.
Kwon, Sook-Kyung C., Erzsebet Kovesdi, Andrea B. Gyorgy, Daniel Wingo, Alaa Kamnaksh, John Walker, Joseph B. Long, and Denes V. Agoston. "Stress and Traumatic Brain Injury: A Behavioral, Proteomics, and Histological Study." *Frontiers in Neurology* 2 (March 7, 2011). https://doi.org/10.3389/fneur.2011.00012.
Lobell, John. *Between Silence and Light: Spirit in the Architecture of Louis I. Kahn*. 2000th ed. Boston: Shambhala, 1979.
Lynch, Kevin. *The Image of the City*. MIT Press, 1960.
Mace, and Heft. "Ecological Approach," 375–80. Encyclopedia of Perception. Sage Publications, 2010.
Marquez, David X., Rebecca H. Hunter, Michelle H. Griffith, Lucinda L. Bryant, Sarah J. Janicek, and Adam J. Atherly. "Older Adult Strategies for Community Wayfinding." *Journal of Applied Gerontology* 36, no. 2 (February 1, 2017): 213–33. https://doi.org/10.1177/0733464815581481.
Mayo Clinic. "Traumatic Brain Injury - Symptoms and Causes." Mayo Clinic. Accessed December 10, 2020. https://www.mayoclinic.org/diseases-conditions/traumatic-brain-injury/symptoms-causes/syc-20378557.

Meehan, Patrick. *Truth Against the World: Frank Llyd Wright Speaks for an Organic Architecture*. The Preservation Press, 1987.
Meili, Trisha. *I Am the Central Park Jogger: A Story of Hope and Possibility*. Scribner, 2004.
Michaels, Claire, and Claudia Carello. *Direct Perception*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1981.
National Institute of Neurological Disorders and Stroke, and National Institutes of Health. "Traumatic Brain Injury: Hope through Research," February 2020. https://www.ninds.nih.gov/sites/default/files/traumatic_brain_injury_htr_february_2020_508c_1.pdf.
Finnish Design Shop COM. "Paimio Sanatorium Is an Impressive Site | Design Stories." Accessed April 17, 2021. https://www.finnishdesignshop.com/design-stories/architecture/alvar-aalto-and-the-colors-of-the-paimio-sanatorium.
Palatinus, Zsolt, and Claire Michaels. "A Ten Commandments for Ecological Psychology," 2014. https://doi.org/10.4324/9781315775845.ch2.
"Patient Ward at Veterans Administration Hospital, October 1953 | Ann Arbor District Library." Accessed April 21, 2021. https://aadl.org/node/314370.
Phelan, Sean M., Joan M. Griffin, Wendy L. Hellerstedt, Nina A. Sayer, Agnes C. Jensen, Diana J. Burgess, and Michelle van Ryn. "Perceived Stigma, Strain, and Mental Health among Caregivers of Veterans with Traumatic Brain Injury." *Disability and Health Journal* 4, no. 3 (July 2011): 177–84. https://doi.org/10.1016/j.dhjo.2011.03.003.
SmithGroup. "Rancho Los Amigos National Rehabilitation Center." Accessed December 10, 2020. https://www.smithgroup.com/projects/rancho-los-amigos-national-rehabilitation-center.
Risen, Clay. "Yehuda Ben-Yishay, Pioneer in Treating Brain Injuries, Dies at 88." *The New York Times*, April 9, 2021, sec. Health. https://www.nytimes.com/2021/04/09/health/yehuda-ben-yishay-dead.html.
Rock, Irvin. *Perception*. New York: Scientific American Library, 1995.
Roeckelein, Jon, ed. "Rotter's Social Learning Theory." In *Elsevier's Dictionary of Psychological Theories*. Elsevier Science & Technology, 2006. http://libproxy.clemson.edu/login?url=https://search.credoreference.com/con

tent/entry/estpsyctheory/rotter_s_social_learning_theory/0?institutionId=1831.

Sternberg, Esther. *Healing Spaces: The Science of Place and Well-Being*. *Bibliovault OAI Repository, the University of Chicago Press*, 2009. https://doi.org/10.2307/j.ctvjghtgs.

Taylor, Jill Bolte. *My Stroke of Insight: A Brain Scientist's Personal Journey*. New York: Penguin, 2006.

"The Glasgow Structured Approach to Assessment of the Glasgow Coma Scale." Accessed December 9, 2020. https://www.glasgowcomascale.org/.

Military Health System. "The NICoE: Ten Years of Healing 'The Invisible Wounds of War,'" June 30, 2020. http://health.mil/News/Articles/2020/06/30/The-NICoE-Ten-year-of-Healing-The-Invisible-Wounds-of-War.

"Traumatic Brain Injury - TBI Multidisciplinary Healthcare Team." Accessed April 14, 2021. https://tbi.cemmlibrary.org/Moderate-to-Severe-TBI/TBI-Multidisciplinary-Healthcare-Team.

Turvey, M. "Perception: The Ecological Approach." In *Encyclopedia of Cognitive Science*, edited by L Nadel, 538–41. Nature Publishing Group, 2003.

Ulrich, R.S. "A Theory of Supportive Design for Healthcare Facilities." *Journal of Health Care Design* 9 (n.d.): 3–7.

Vaz, Daniela Virgínia, Paula Lanna Silva, Marisa Cotta Mancini, Claudia Carello, and Jeffrey Kinsella-Shaw. "Towards an Ecologically Grounded Functional Practice in Rehabilitation." *Human Movement Science* 52 (April 1, 2017): 117–32. https://doi.org/10.1016/j.humov.2017.01.010.

Walsh, R. Stephen, Orla T. Muldoon, Stephen Gallagher, and Donal G. Fortune. "Affiliative and 'Self-as-Doer' Identities: Relationships between Social Identity, Social Support, and Emotional Status amongst Survivors of Acquired Brain Injury (ABI)." *Neuropsychological Rehabilitation* 25, no. 4 (July 4, 2015): 555–73. https://doi.org/10.1080/09602011.2014.993658.

Werner, Steffen, and Laura E. Schindler. "The Role of Spatial Reference Frames in Architecture: Misalignment Impairs Way-Finding Performance." *Environment* *and Behavior* 36, no. 4 (July 1, 2004): 461–82. https://doi.org/10.1177/0013916503254829.

SmartAdvocate® - The best plaintiff personal injury case management software. “What Happens When You Get a Brain Injury in Different Areas of Your Brain?” Accessed December 11, 2020. https://www.smartadvocate.com/News/Blog/what-happens-when-you-get-a-brain-injury.

Wilson, Alex. “How to Make a Hospital Resilient: A Tour of Spaulding Rehab.” *Resilient Design Institute* (blog), February 3, 2015. https://www.resilientdesign.org/how-to-make-a-hospital-resilient-a-tour-of-spaulding-rehabilitation-center/.

Withagen, Rob, and Claire Michaels. “The Role of Feedback Information for Calibration and Attunement in Perceiving Length by Dynamic Touch.” *Journal of Experimental Psychology. Human Perception and Performance* 31 (January 1, 2006): 1379–90. https://doi.org/10.1037/0096-1523.31.6.1379.

Woodruff, Lee, and Bob Woodruff. *In an Instant: A Family’s Journey of Love and Healing*. Random House Trade Paperbacks, 2008.

World Health Organization. “Towards a Common Language for Functioning, Disability and Health: ICF,” 2002.